Revisions to the Phase II Pawtuxet River Proposal

CIBA–GEIGY Facility
Cranston, Rhode Island

Submitted by:

CIBA–GEIGY Corporation

444 Sawmill River Road

Ardsley, New York 10502

October 1993

PREFACE

This document presents revisions to the Phase II Pawtuxet River Proposal (submitted in January 1992) for the RCRA Facility Investigation of the CIBA-GEIGY facility at Cranston, RI. These revisions address comments received from the USEPA in a letter dated 10 September 1993.

Organization of This Document

This binder has specific tabs (indexed dividers) corresponding to the chapter/appendix revised. Some of these revisions are presented on revised (replacement) pages, tables, and/or figures. Note that Appendix F was not included in the original Phase II Pawtuxet River Proposal; it addresses Comment #14 in the USEPA comment letter (9/10/93).

The tabs in this binder are:

- *Chapter 2* — contains revised pages 2-4, 2-6, and 2-6a.
- *Chapter 4* — contains revised pages 4-5, 4-5a, and new Figure 4-1.
- *Chapter 5* — contains revised pages 5-5 to 5-12, revised Tables 5-1 and 5-2, and new Table 5-3.
- *Chapter 6* — contains replacement text for Chapter 6, and revised Figure 6-2.
- *Appendix C* — contains revised pages C-4 and C-4a.
- *Appendix D* — contains revised pages D-1, D-1a, D-5, and D-5a.
- *Appendix E* — replaces the original version of Appendix E, except Figure E-1.
- *Appendix F* — a new addendum to this Phase II Pawtuxet River Proposal.

Key to Comments/Revisions

The following table summarizes how and where each of the USEPA comments are addressed.

Comment Numbers	Topic (Brief Description)	Addressed in/by	Found in Tab
1	Outfall 005	Revised page 2-4	2
2	Fourth-order streams	Revised pages 2-6 and 2-6a	2
3–4	*(As suggested in the USEPA comment letter, these comments will be addressed in the RFI Report.)*		
5	Show location of Cranston gauge and Pawtuxet Cove Dam	New Figure 4-1	4
6–7	*(As suggested in the USEPA comment letter, these comments will be addressed in the RFI Report.)*		
8	Depth range of surficial sediment samples (0-6 inches)	Revised pages 4-5 and 4-5a	4
9	Same or different transects for Phases I and II	Revised pages 4-5 and 4-5a	4
10	Various text/table changes pursuant to approved analyte list	Revised pages 5-5, 5-7 to 5-12, Tables 5-1 and 5-2	5
11	*(As suggested in the USEPA comment letter, this comment will be addressed in the RFI Report.)*		
12	Round 2 samples from the upper facility reach	Revised pages 5-6 and 5-11	5
13	Rationale for not sampling surficial sediment in upper reach	Revised page 5-7	5
14	Evaluating vertical extent of contamination in lower reach	Addressed by addendum in (new) Appendix F	F — Review
15–44	(Various comments on Chapter 6)	Replaced text of Chapter 6; revised Figure 6-2	6
45	How sampling handling may affect concentrations/toxicity	Revised pages C-4 and C-4a	C
46	Pore water toxic to midge larvae	Revised pages C-4 and C-4a	C
47	Source of rating curves	Revised pages D-1 and D-1a	D
48	Round 2 discharge value may be too high	No changes; see "Responses to Comments" (next)	
49	*(As suggested in the USEPA comment letter, this comment will be addressed in the RFI Report.)*		
50	Sulfide concentration of 14 mg/l is high	No changes; see "Responses to Comments" (next)	
51	Evaluate how sampling methods may reduce concentrations	Revised pages D-5 and D-5a	D
52	*(As suggested in the USEPA comment letter, this comment will be addressed in the RFI Report.)*		
53–55	(Various comments on Appendix E)	Replaced Appendix E entirely, except Figure E-1	E — Review
56–63	(Various comments on HydroQual document submitted 9/92)	Addressed in Appendix E	E — Review
64	(Comment on proposed list of sediment analytes)	New Table 5-3	5

TECHNICAL REVIEW - PHASE II PAWTUXET RIVER PROPOSAL

AND OTHER RIVER RELATED DOCUMENTS

The following comments are provided as the basis for EPA's **Disapproval** of Ciba-Geigy's Phase II Pawtuxet River Proposal.

CHAPTER 2 - PHASE I HYDROLOGICAL INVESTIGATION

1. **Page 2-4:** There is no discussion on Outfall 005.

   A discussion of outfall 005 is provided on revised page 2-4.

2. **Page 2-6:** What is a fourth order stream?

   This comment is addressed on revised page 2-6.

CHAPTER 3 - PHASE I RELEASE CHARACTERIZATION

3. The Phase I Interim Report and Phase II Proposal and the Pawtuxet River Proposal attempts to present a reduced version of the analytical data by using summary tables which display the data in several different ways. This appears throughout the both documents. In developing these tables certain assumptions are made and statistical parameters are met. EPA questions the picture these assumptions and statistical parameters present and would like to amend and approve their use in any summary tables prior to inclusion in the RFI Report. For the record, EPA questions the method of selecting the "Baseline Concentrations", the calculation of the "Mean Total Concentration" and the presentation of the "# of analytes detected".

   This issue will be addressed with USEPA prior to developing the RFI Report.

4. There should be some discussion on published background concentrations for sediments.

   This issue will be addressed with USEPA prior to developing the RFI Report.

CHAPTER 4 - PHASE II HYDROLOGICAL INVESTIGATION PROPOSAL

5. **Page 4-2:** A map or reference showing the location of the USGS Cranston gauge and the Pawtuxet Cove Dam needs to be provided.

   A figure showing the locations of the USGS Cranston gauge and the Pawtuxet Cove Dam is provided (see Figure 4-1).

6. **Page 4-4:** The distance between transects used to determine sediment depths must be provided and their location shown on a map of the river.

This information was provided to USEPA at a September 1992 meeting held in Boston, MA. This information also will be included in the RFI Report.

7. The sediment sampling strategy should describe the basis for the transect spacing, sampling intervals and sediment probing and why they are appropriate for determining particle size variations in the stream bed, sediment depth and sampling locations for contamination.

   This information was provided to USEPA at a September 1992 meeting held in Boston, MA. This information also will be included in the RFI Report.

8. **Page 4-5:** The depth range for "surficial sediment" should be presented and it should be in the 0-6 inch range.

   Sediment samples will be collected using coring methods wherever possible. The top six inches of sediment will represent the surficial sample. If sediment cores cannot be collected and ponar or other grab sample methods are required, every attempt will be made to sample the top six inches, but the exact penetration of the grab sampler will vary depending upon sediment type (see revised page 4-5).

9. Will the same transects be used in Phase II as was used in Phase I for the upstream, downstream and facility reaches or will new transects be used? This should be clarified.

   The transects used in Phase I were established for measurement of river bathymetry. The location of some transects for physical characterization of sediment in Phase II coincide with Phase I transects, but many additional transects have been added in Phase II (see revised page 4-5).

CHAPTER 5 - PHASE II RELEASE CHARACTERIZATION

10. Tables and narrative changes should be made upon approval of the analyte lists.

    Revised text and tables reflecting USEPA's approval of the analyte list are included in Chapter 5.

11. **Page 5-3:** As discussed in paragraphs 3 & 4, any sediment sampling location and transect that is selected based on its being "downstream of potentially significant input sources" should be reviewed with EPA prior to selection and discussed in the RFI Report.

    All upstream reach transects and sediment locations will be reviewed with the USEPA prior to sampling. These locations also will be discussed in the RFI Report.

12. **Pages 5-6 & 11:** Will there be any round 2 samples for the upper facility reach? This should be clarified.

No Round 2 samples will be collected from the upper facility reach as this area will have been sampled extensively by the completion of Round 1 (see revised page 5-6).

13. **Page 5-7:** What is the rationale for not taking surficial sediment samples in the upper facility reach?

Surficial sediment samples will not be collected in the upper facility reach because surface sediments were extensively sampled during Phase I (see revised page 5-7).

14. The text on page 5-7 & 8 states that evaluation of the vertical extent of contamination in the lower facility reach will not be performed if surface sediment contamination is not detected in that area. The proposal should fully discuss the basis for this approach. The discussion should focus on benthic studies, exposure scenarios, and erosion and deposition rates and should include supporting material. Since the lower facility reach is down stream from the contaminated upper facility reach, it is possible that significant contaminant deposition may have occurred. It is also possible that changes in river conditions may have caused subsequent deposition of uncontaminated sediment on the surface. If there is no valid basis for the existing sampling approach then the proposal should state that subsurface sediments in the lower facility reach will be collected in round 2 to confirm the vertical limits of contamination and the sampling approach should be explained.

A discussion of the basis for the Phase II Release Characterization sampling plan for the lower facility Reach is presented in Appendix F.

CHAPTER 6 - PHASE II ENVIRONMENTAL ASSESSMENT PROPOSAL

15. **General:** The criteria for deciding what constitutes a "significant concern" and the communicating of these decisions to EPA should be included. For example, on page 6-12 the 2nd paragraph states that if the screening level risk assessment for riparian receptors indicates no "significant concern", then no further riparian investigations will be performed.

This comment has been addressed on page 6-23 (Section 6.5.4), Conducting Terrestrial Environment Investigations (Task 4).

16. **Pages 6-4 & 8:** The performance of tasks 3 & 4 on page 6-8 should not be contingent upon the results of task 2 on page 6-4 as the phrase "if necessary" indicates.

The phrase "if necessary" has been deleted on page 6-14 (Section 6.4), Paragraph entitled: Conducting a Literature Review (Task 2).

17. **Page 6-5:** The 4th bullet under the Task 3 heading discusses assessing the impact of site-related constituents on aquatic biota by comparing community indices. The proposal does not indicate the standard of comparison. Note that differences in these indices may be caused by physical conditions in the environment such as differences in flow, aquatic vegetation, or substrate. If differences are observed, it may be difficult to attribute them to site-related contaminants.

This issue is addressed on page 6-8 (Section 6.4), Conducting Aquatic Environment Investigations (Task 3).

18. **Page 6.5:** If plans are to include an analysis of community level effects, the proposal should elaborate on the specific indices; the acceptance of such comparisons in the scientific literature; the basis of comparison; the statistical validity of the indices; and the range of values for the index within similar systems. Since there are numerous indices in the literature which are commonly misused, a complete understanding of the index or indices and their applicability should be presented in the river proposal.

This issue is addressed on page 6-8 (Section 6.4), Conducting Aquatic Environment Investigations (Task 3).

19. **Page 6-7:** What does "miscellaneous adjustments of water quality" mean. This should be defined.

An explanation is provided on 6-13 (Section 6.5.1), Conducting Toxicity Identification Evaluations (Task 1), Step 4: Confirming the cause of toxicity.

20. **Page 6-8:** The characterization of aquatic populations and the characterization of the ecosystem are listed as separate bullets although aquatic populations are a subset of the ecosystem. The term "characterization of the ecosystem" should be defined.

This issue is addressed on pages 6-15 and 6-16 (Section 6.5.3), Conducting Aquatic Environment Investigations (Task 3), Habitat Characterization.

21. **Page 6-9:** The characterization of aquatic populations via field surveys should explicitly state that the results of the field surveys will be compared to the information obtained during the literature review.

This issue is addressed on page 6-16 (Section 6.5.3), Conducting Aquatic Environment Investigations (Task 3), Characterization of Aquatic Populations.

22. **Page 6-9:** The fish sampling program calls for deployment of gill nets throughout the night. This could result in a large number of fish being caught. Consideration should be given to the need for full night deployments. A two- or four- hour set should be adequate for a river. It should also be noted that most of the fish caught by gill net will be damaged to some extent and expectations for survival after release back to the environment are low. Although gill netting is an effective method to use, the opportunity to release fish unharmed is minimal.

This issue is addressed on pages 6-16 and 6-17 (Section 6.5.3), Conducting Aquatic Environment Investigations (Task 3) Fish Population Survey. Gill netting has been deleted and will not be conducted.

23. **Page 6-9:** The data to be recorded from fish samples should also include taking scales from some of the fish to provide estimates of age. Consideration should also be given to the measurement of body burdens of specific chemicals of concern. Such measurements would provide a measure of exposure to fish and also indicate the degree to which fish may be a source of exposure to animals higher in the food webs. A decision should be based on a review of chemicals present in the sediments and soils and the potential for bioaccumulation and transfer via food webs. If there is concern regarding exposure to chemicals that can be metabolized (e.g., PAH's) then it would be necessary to measure the metabolite level in the liver.

These comments are addressed on page 6-17 (Section 6.5.3), Conducting Aquatic Environment Investigations (Task 3), Fish Population Survey.

24. **Page 6-9:** The last paragraph indicates that a field decision (presumably based upon fish species collected) will be made regarding distance between furthest upstream and downstream transects. The rationale for this decision should be provided. Depending upon the species encountered, this distance could be so large as to make interpretation of differences between fish populations from the different transects quite speculative. The proposal should include the rationale and describe under what circumstances the furthest upstream and downstream transects would be extended.

This issue is address on page 6-17 (Section 6.5.3), Conducting Aquatic Environment Investigations (Task 3), Fish Population Survey.

25. **Page 6-10:** The text states that the physical characteristics of the sample area will be recorded. The types of characteristics to be recorded should be listed.

The characteristics are listed on page 6-17 (Section 6.5.3), Conducting Aquatic Environment Investigations (Task 3), Fish Population Survey.

26. **Page 6-10:** The benthic sampling program should be designed so that comparable sediment types (soft or hard bottom areas) and flow regimes are sampled above, at, and below the facility. This is not explicitly discussed in the document. An effort should be made to minimize habitat differences among sampling areas so that the possible effects of chemicals can be discerned. Consideration should be given to examining soft (fine sand and silt) bottom areas in preference to hard bottom of coarse sand areas because more species are likely to be present.

This issue addressed on page 6-18 (Section 6.5.3), Conducting Aquatic Environment Investigations (Task 3), Benthic Macroinvertebrate Survey .

27. **Page 6-10:** The second bullet lists two endangered invertebrate species whose presence or absence well be investigated in the benthic survey without any reference to the source of the information. The source of the information on endangered species should be referenced as well as the reasons why these species might be expected in the vicinity of the site.

This comment is addressed on page 6-19 (Section 6.5.3), Conducting Aquatic Environment Investigations (Task 3), Benthic Macroinvertebrate Survey.

28. **Page 6-11:** If impairment is found in benthic communities based on the presence of absence of indicator species or differences in community structure as stated in the first bullet, it may be difficult to attribute the impairment to site-related contaminants rather than physical characteristics of the environment. See also the constraints upon the use of such indices as noted in the comment regarding Page 6-5.

This comment is addressed on page 6-20 (Section 6.5.3), Conducting Aquatic Environment Investigations (Task 3), Benthic Macroinvertebrate Survey.

29. **Page 6-11:** The second bullet states that the information gathered during the benthic survey will allow the investigators to "determine the applicability of bioassay test organisms." Additional information should be provided to describe how this will be accomplished.

This comment is addressed on page 6-20 (Section 6.5.3), Conducting Aquatic Environment Investigations (Task 3), Benthic Macroinvertebrate Survey.

30. **Page 6-11:** Section 6.5.4 does not mention plants as potential receptors. A description of plant communities in the vicinity of the site should be made to identify potential habitats for bird and mammal species.

This comment is addressed on pages 6-23 and 6-24 (Section 6.5.4), Conducting Terrestrial Environment Investigations (Task 4), Site Visit.

31. **Page 6-11:** The Screening-Level Risk Assessment section needs to be clarified. It is likely that the word "or" should follow the first three bullet points. As it reads now, the section implies that only organisms that are chronically exposed to site-related chemicals, endangered or threatened, of economic importance, and chemically exposed via pathways different from those of organisms chronically exposed to site-related chemicals will be assessed.

This comment is addressed on page 6-24 (Section 6.5.4), Conducting Terrestrial Environment Investigations (Task 4), Screening-Level Risk Assessment.

32. **Page 6-11:** Explain the last bullet on this page.

The last bullet has been clarified on page 6-24 (Section 6.5.4), Conducting Terrestrial Environment Investigations (Task 4), Screening Level Risk Assessment.

33. **Page 6-12:** The riparian surveys will be performed contingent upon the results of the screening-level assessment described on Page 6-11. Refer to the general comments for this section regarding the criteria on which to base the decisions to perform additional tasks.

This comment is addressed on page 6-23 (Section 6.5.4), Conducting Terrestrial Environmental Investigations (Task 4), Screening Level Risk Assessment.

34. Will there be any analysis of animals for site related chemicals? This should be included if the environmental evaluation is going to consider food chain related effects as this can reduce the uncertainty inherent in a food chain model based on many assumptions.

This issue is addressed on page 6-25 (Section 6.5.4) Conducting Terrestrial Environmental Investigations (Task 4), Riparian Surveys.

35. **Page 6-13:** The bird surveys lists endangered species without reference to the source of this information. The source of this information and the reasons for expecting these birds to be found in the vicinity of the site should be included.

This comment is addressed on page 6-28 (Section 6.5.4), Conducting Terrestrial Environmental Investigations (Task 4), Bird Surveys.

36. **Page 6-15:** The section titled "Hazard Identification" is under Section 6.5.5 Performing an Ecological Assessment of

the Pawtuxet River (Task 5). The toxicity information discussed in this section may not be available for all constituents of concern. The proposal should include a discussion on how chemicals without available toxicity information will be evaluated (e.g. on the basis of homologous chemicals).

This issue is addressed on page 6-31 (Section 6.5), Performing an Ecological Assessment of the Pawtuxet River (Task 5), Hazard Identification.

37. **Page 6-15:** The variables that influence toxicity that are discussed in this section should be included in the discussion of uncertainty in the uncertainty section.

This comment is addressed on page 6-33 (Section 6.5.5.), Performing an Ecological Assessment of the Pawtuxet River (Task 5), Uncertainty Analysis.

38. **Page 6-15:** Note that there may not be information available for carcinogenic and non-carcinogenic effects on ecological receptors as discussed in the Dose-Response Assessment section. Carcinogenic and noncarcinogenic effects information is more applicable to human receptors.

This comment is addressed on page 6-31 (Section 6.5.5.), Performing an Ecological Assessment of the Pawtuxet River (Task 5), Dose Response Assessment.

39. **Page 6-15:** The Determination of Ecological Endpoints section should note that there may not be any information available on population, community, or ecosystem endpoints. The use of indices such as diversity, food-web diversity, and productivity are subject to much uncertainty and have natural variations that are likely to mask any "signal." The current scientific literature is barely adequate to address individual endpoints. It is overly optimistic to propose the use of population, community, and ecosystem endpoints. There is simply inadequate knowledge to identify these except in the most extreme cases. Also the plan proposes to use endpoints for which there will be no site specific data (e.g. population growth rate, frequency of disease, productivity). This should be addressed.

This comment is addressed pages 6-31 and 6-32 (Section 6.5.5), Performing an Ecological Assessment of the Pawtuxet River (Task 5), Determination of Ecological Endpoints.

40. **Page 6-16:** The second bullet refers to "reference" areas but the text never discusses the identification of reference areas or how to assess whether a given area is an appropriate reference area.

This comment is addressed on page 6-33 (Section 6.5.5.), Performing an Ecological Assessment of the Pawtuxet River (Task 5), Risk Analysis.

41. **Page 6-16:** The phrase "comparing intake rates and reference cases" should be clarified.

This comment is addressed on page 6-33 (Section 6.5.5), Performing an Ecological Assessment of the Pawtuxet River (Task 5), Risk Analysis.

42. **Page 6-16:** The fourth bullet mentions "biomarkers or bioaccumulation methods." This should either not be mentioned in this section or qualified with the statement that this information will be gathered contingent upon the outcome of the screening-level risk assessment. Tissue analysis was only mentioned briefly as a contingency on Page 6-11, Paragraph 2 regarding a species-specific fish survey.

This comment is addressed on page 6-33 (Section 6.5.5), Performing an Ecological Assessment of the Pawtuxet River (Task 5), Risk Analysis. The fourth bulleted statement has been deleted.

43. **Page 6-16:** The phrase "quantitative fault/event tree analysis" should be clarified.

This comment is addressed on page 6-33 (Section 6.5.5), Performing an Ecological Assessment of the Pawtuxet River (Task 5), Risk Analysis. The fifth bulleted statement has been deleted.

44. **Page 6-16:** The section on Uncertainty Analysis should be expanded as there will be uncertainty associated with each task of the assessment.

This comment is addressed on page 6-33 (Section 6.5.5), Performing an Ecological Assessment of the Pawtuxet River (Task 5), Uncertainty Analysis.

APPENDIX C - BIOASSAY METHODOLOGIES

45. **Page C-4:** There should be some discussion on how the sample handling procedures (stirring, centrifuging and vacuum-filtering) may affect exposure concentrations and, therefore, toxicity of both pore water and sediments to the organisms being tested. This discussion could be included in this Appendix or Chapter 3 and should be accounted for in the Phase II proposal.

Appendix C has been amended to include a discussion of the effect of sample handling on toxicity (Page C-4).

46. **Page C-4:** The 3rd sentence in the 4th paragraph says the pore water was toxic to midge larvae. Is this correct?

*The third sentence in the 4th paragraph on Page C-4 of Appendix C has been corrected to read, "...pore water from two fo these six samples was toxic to **Cerrodaphnia dubia**.*

APPENDIX D - FLOW CONDITIONS AND PHYSICOCHEMICAL DATA

47. **Page D-1:** The 3rd paragraph should explain and reference the source of the rating curves discussed in this section.

This comment is addressed on revised page D-1.

48. **Page D-1:** The next to the last paragraph uses 1040 cfs as the discharge for round 2 when calculating the suspended sediment discharge estimate. Since this number originated at the Cranston gauge and it was the highest measured value it may be too high to use for the site. Round 1 shows a 35% difference from the estimated site value to the Cranston Gauge value. This may overestimate the suspended sediment value and consequently the calculation of the contaminant partition coefficient in the Phase II modelling of the river. If more accurate site information exists or will be obtained, this should be stated. If not, a detailed explanation of how the difference in values affects the model should be included. In any event, this issue should be examined prior to running the model since changes in the model may influence decisions made in the future.

As stated in the first sentence of Appendix D, "..This appendix describes the flow conditions of the Pawtuxet River during the Phase I release characterization sampling activities..". The purpose of this appendix is to provide a qualitative assessment of field conditions during sampling activities. The paragraph discussion on total suspended sediment concentrations is provided as reference for field conditions during sampling. No calculations of contaminant partition coefficients will be made from this value. The Phase II model of the river system includes a sediment transport component that has been developed independently from this effort. No changes will be made in this paragraph.

49. Ranges should be provided when estimating values and the appropriate number of significant figures should be used.

This issue will be clarified in the RFI Report.

50. **Page D-3:** A sulfide concentration of 14 mg/l is high, especially considering that the water is well oxygenated. It also appears that all the high readings were detected in the 11/27/90 samples. There should be some discussion of the variation in values in terms of the sampling and analysis methods and whether they were appropriate and followed adequately.

Field procedures were followed consistently during surface water sampling (performed on November 26-27, 1990). The sulfide concentrations did vary across the samples collected on these two days. Because this analysis was part of the treatability data deliverable, supporting QA documentation was not provided and validation could not be performed. An effort was made to contact the laboratory which performed the analyses to request the supporting QA documentation, but this laboratory is no longer operating. As agreed by USEPA, selected surface water samples collected during Phase II will be analyzed for sulfide.

51. **Page D-5:** The last paragraph in section D.4 explains the differences in ammonia and sulfide concentrations from sample to sample. This discussion should evaluate the sampling methods since grab samples are more likely to be exposed to atmospheric oxygen which can oxidize ammonia and sulfide thereby reducing concentrations.

    This issue has been addressed in revised Section D.4 (see revised page D-5).

52. **Table D-4:** Listing only the median grain size for each sample does not provide enough information to understand the size distribution of the sediment. Grain size plots showing the percent gravel, sand, silt, and clay should be provided.

    The information requested will be included in the RFI Report.

APPENDIX E - PHASE II MODELING OF THE PAWTUXET RIVER

53. **General:** Since several assumptions and simplifications must be made to implement this model, a sensitivity analysis must be performed to determine the "volatility" of the model to inadequate parameterization.

    A discussion of sensitivity analyses has been added in section E.4.9 on page E-23.

54. **Page E-12:** The selection of the statistical technique to be used to handle detection limit issues should be discussed with EPA prior selection and use.

    The selection of statistical techniques used to handle detection limit issues will be discussed with USEPA prior to selection and use, as discussed on page E-16.

55. **Page E-17:** The proposed discretization of the 3 reaches into a 3 cell by 10 cell grid will allow only a general understanding of contaminant migration in the river. Based on the volume of data which currently exists or will be obtained prior to the modeling effort, a finer grid could be efficiently utilized.

The model segmentation proposed for the contaminant fate model is discussed on page E-23.

PAWTUXET RIVER SEDIMENT SAMPLING PROGRAM - HYDROQUAL 9-18-92

56. **General:** The Pawtuxet River sediment sampling program has been incorporated into section E.4.3 of Appendix E.

A discussion of postponing sediment sampling after significant rain events has been added to page ~~E-23~~ E-9.

57. The Phase II Pawtuxet River Proposal and the HydroQual proposal do not provide a comprehensive discussion of the intended model vertical discretization and it is not possible to evaluate the adequacy of the proposed sampling plan to support the objectives of the model. It is not clear how deep the model is intended to extend, nor if the depth of sampling is sufficient to satisfy the needs of the model. Nor is it clear on how many vertical layers will be used and whether samples will be obtained for each layer.

A discussion of the proposed model segmentation has been added to page E-23.

58. **Page 2:** Since the proposed plan does not intend to sample all of the river cells, it would be more technically appropriate to use different cell sizes in different portions of the river. Smaller cells should be used in areas where the greatest variability exists (i.e., adjacent to the facility). This appears to be the case when viewing the Appendix 1 map titled Pawtuxet River Sediment Sampling Areas but the text does not state that this is how the cells were chosen.

A statement has been added to page E-10 which indicates that the sediment grid was designed with smaller cells in the Facility Reach where the greatest variability in sediment contaminant concentrations are expected.

59. **Page 2:** The text states that concentrations in unsampled grid elements may be interpolated based on concentration gradients and relevent physical characteristics such as sediment type and TOC content. This is a valid use of the model but there is no provision for verifying these interpolated concentrations to see how accurate the model is functioning. A verification program should be developed which discusses how verification will be accomplished, what is acceptable performance and how unacceptable performance will be evaluated and corrected.

A discussion of sediment contaminant concentration interpolation has been added to page E-16.

60. **Page 9:** The text states that in areas where cores can not be collected, grab samples from the upper 5 centimeters (2

inches) will be collected. This is a large variation in sampling depths between grabs (5cm) and push (40cm) samples. How will this affect the model? Should grabs be deeper?

A discussion of the consistency between 5 centimeter sediment grab samples and the top slice of sediment cores has been added to page E-11.

61. **Page 10:** What does "like depth intervals from the five cores from each sampling area will be composited" mean. What are the depth intervals? Will there be more than 1 sample per location based on depth?

A discussion how sediment cores will be sectioned for analysis has been added to page E-11.

62. **Page 10:** Are sample handling, analysis and decontamination procedures the same as for the release characterization study?

A statement concerning sample handling, analysis and decontamination procedures has been added to page E-11.

63. **Page 10:** How and when will samples be dried to determine total solids fraction? Since the drying process will cause the VOA's to be driven off will the VOA's be analyzed prior to drying. The scope of the analysis of the centrate after the centrifuge process is unclear. Since the centrifuge process will cause the VOA's to be driven off will the VOA's be analyzed prior to centrifuging. This page should be explained in more detail.

A discussion has been added to page E-11 to clarify these issues.

RATIONALE FOR PROPOSED LIST OF SEDIMENT ANALYTES - IT CORP 9-8-92

64. **Page 4:** The list of analytes for the Pawtuxet River Sediment Release Characterization should include the compound "bis (2-Ethylhexyl) phthalate". The total list of analytes for the Release Characterization including the limited sampling for dioxins/furans should be tabulated and submitted with the revised Phase II Pawtuxet River Proposal.

The analyte list (approved by USEPA) for the Pawtuxet River Release Characterization is summarized in Table 5-3.

and 1788 cubic feet per second (April 1983), respectively. The Providence USGS-WRD has generated a rating table for the Pawtuxet River at Cranston, relating discharge to river stage. Figure 2-7 is a rating curve based on discharge values from the rating table for every 0.10-foot increment of stage.

The elevations of surface water bodies in the vicinity of the site were checked on a topographic map; all the surface water bodies are topographically upgradient of the site. Therefore, the Pawtuxet River is the only surface water body topographically downgradient of the facility.

The drainage patterns were evaluated in the portion of the Production Area south of the railroad tracks during a heavy rain. The runoff directions were observed at a number of locations and were sketched onto a map of the area. Then this field map was superimposed on a topographic map of the area. The runoff directions closely followed the topographic gradients in the area. Ultimately, water pooled in the southernmost portion of the Production Area and subsequently infiltrated the ground or evaporated.

2.4.2 Summary of Known Discharges to the Pawtuxet River

The Pawtuxet River has received discharges from many industries and several sewage treatment plants since the beginning of the industrial revolution. Before the industrial revolution (1800s) and dating back to the 1700s, forges and textile mills discharged to the Pawtuxet River; privies serving up to 3000 employees were positioned directly over the river.

Originally, the major discharge from the facility to the Pawtuxet River occurred through the cofferdam/waste water outfall associated with the Production Area. That structure was used until the on-site Waste Water Treatment Plant began operation in November 1975. CIBA-GEIGY personnel have identified the location and nature of other outfalls to the river that were used before the on-site Waste Water Treatment Plant was constructed. These outfalls are shown in Figure 2-8. Outfall A was a sanitary overflow outfall for the cafeteria, locker room, and maintenance buildings (Warwick Area). Outfall B was ground surface drainage from the parking lot and maintenance areas (Warwick Area). Outfall C, a pipe visible on the bulkhead, was the discharge pipe for Buildings 4, 4A, and 1 (Production Area). Outfall D was the cofferdam/waste water outfall described earlier. Outfall E was the water recovery, overflow, and drain for the cofferdam. Finally, Outfall F was surface drainage from Roberts Circle and from the tops of Buildings 20 and 26.

As part of operating the Waste Water Treatment Plant, CIBA-GEIGY was permitted under NPDES permit RI 0001171 to discharge treated water to the Pawtuxet River via Outfall 001 (shown in Figure 2-8). Other regular discharges to the Pawtuxet River included water from the cooling tower; that water entered the river via Outfall 002. Water used for cooling purposes in the Warwick Area discharged to the Pawtuxet River via Outfalls 003 and 004. Finally, stormwater run-off from the Waste Water Treatment Area was diverted to half-round culverts (24 inches in diameter) and discharged to the Pawtuxet River via Outfall 005. These culverts also were used to control the level of the pond in SWMU-10.

The impact of past discharges to the Pawtuxet River was studied during the RCRA Facility Assessment. As part of the Facility Assessment, Pawtuxet River sediments along the facility reach were sampled and analyzed for volatile and semi-volatile organic compounds, metals, and pesticides/ PCBs. The results showed metals and organic contaminants at various levels. Similar contaminant levels also were observed in a sediment sample collected 200 feet upstream of the facility. Two facility reach sediment samples were analyzed for tetrachlorodibenzodioxins (TCDD) and -furans (TCDF), but these compounds were not detected. The results of the Facility Assessment sampling are discussed more fully in the Current Assessment Summary Report, in Volume 1 of the RCRA Facility Investigation Proposal.

ranges from 30% to 80%. In other words, the highest discharge measured during the hydrological investigation has been equalled or exceeded only 30% of the time over the USGS period of record; similarly, the lowest discharge measured has been equalled or exceeded about 80% of the time over the period of record. This comparison of measured discharge values to USGS statistics indicates that the discharge values measured during the hydrological investigation bracket a discharge range that occurs about 50% of the time over the period of record.

2.4.5 Suspended Sediment Discharge Along the Facility Reach

Suspended sediment discharge was measured during all three monitoring events; the suspended sediment discharge values also are presented in Table 2-1. Suspended sediment discharge is the mass of suspended sediment travelling past a transect per unit time. Potential sources of suspended sediment are:

- material mobilized from the riverbed;
- material transported into the river from the watershed; and
- material deposited into the river from the atmosphere.

The "order" of a stream describes the ranking of channels within a channel network or drainage system. The smallest fingertip tributaries are "first-order" streams. A second-order stream is formed at the confluence of first-order streams, a third-order stream is formed at the junction of second-order streams, and so on. Since the Pawtuxet River along the facility reach is a fourth-order stream, suspended sediment discharge in the facility reach represents the cumulative amount of sediment entrained from sources throughout almost the entire watershed. Therefore, one should not assume that the suspended sediment mass at the facility reach is derived entirely from facility reach sediments. On the contrary, it is likely that only a very small proportion of the suspended sediment discharge is derived from facility reach sediments.

Each suspended sediment discharge value in Table 2-1 represents the mass of suspended sediment passing the transect per second at the time of surveying. At DSU, the suspended sediment discharge ranged from 10 to 158 grams/sec (864 to 13,651 kg/day). At DSD, the range was 3 to 218 grams/sec (259 to 18,835 kg/day). Suspended sediment concentrations in individual samples ranged from not detected (less than 3 mg/l) to 22 mg/l. Figure 2-9 shows suspended sediment discharge as a function of water discharge for both DSU and DSD; under the water discharge conditions observed during the three monitoring events, suspended sediment discharge increases with increased water discharge. This direct relationship probably reflects the higher sediment carrying capacity of the river under increased flow conditions.

2.4.6 Physicochemical Characteristics of Sediments Along the Facility Reach

Riverbed sediments were collected by push coring and grab sampling. (The sampling locations are shown in Figures 2-4 and 2-5.) In general, the riverbed sediments were coarse-grained in most areas, ranging from sand to gravel. The exception is the reach adjacent to the Production Area, where silts and fine sands were collected. The samples were collected from locations where conditions permitted retrieval of a sample. Sampling was unsuccessful at some locations where the riverbed was very hard-packed and/or armored by large cobbles. The detailed results of grain size analyses were presented in Appendix F of the Phase I Interim Report.

Table 2-2 presents the porosity and total unit weight of sediment cores collected during the release characterization sampling. These values may not be representative because cores were collected only in finer-grained material; coring attempts in more coarse-grained material were unsuccessful. Therefore, the porosity and total unit weight data are not representative of all Pawtuxet River sediments. Table 2-2 also shows the median grain size for each sediment sample

collected, as well as the USCS classification for each sample. Porosity values ranged from 59% to 84%; the highest value occurred in a silt sample. The total unit weights ranged from 75 to 108

until resistance prevents further penetration. The distance the probe is inserted into the sediment will then be recorded, along with the exact location of the probe (which is logged to the computer using the EDMI devices). Sediment depths will be measured to the nearest 0.5 foot. So far as possible, the same personnel will be used throughout the probing to ensure that measurements are taken in a consistent manner.

4.5.2 Quantifying Sediment Physical Characteristics

Surficial sediment samples will be collected:

- in the facility reach (which is about 2000 feet long) along transects spaced about 100 feet apart;
- in the upstream and downstream reaches (both of which are about 5000 feet long) along transects spaced about 500 feet apart; and
- in the extended upstream and extended downstream reaches (which have a combined length of about 2.5 miles) along 10 transects spaced about 0.25 miles apart.

(In some instances, these transects coincide with transects used for evaluating river bathymetry in Phase I.)

Three samples will be collected along each transect (where sediments are present) using remote sampling devices (i.e., Ponars or corers). The exact locations of these samples will be logged into a field computer using the EDMI devices. Wherever possible, surficial sediment samples will be collected from the top 6 inches (0–6 inches) of sediment. If sampling methods or sediment thickness prevents collecting sediment from the top 6 inches, the depth of the sample collected will be measured or estimated and recorded in the field log. A qualitative description of each sample also will be recorded, classifying the sample as fine- or coarse-grained.

The surficial sediment samples will be analyzed for five parameters:

- particle size;
- TOC;
- bulk density;
- moisture content; and
- combustibility (only for sediment samples from the area of the former cofferdam).

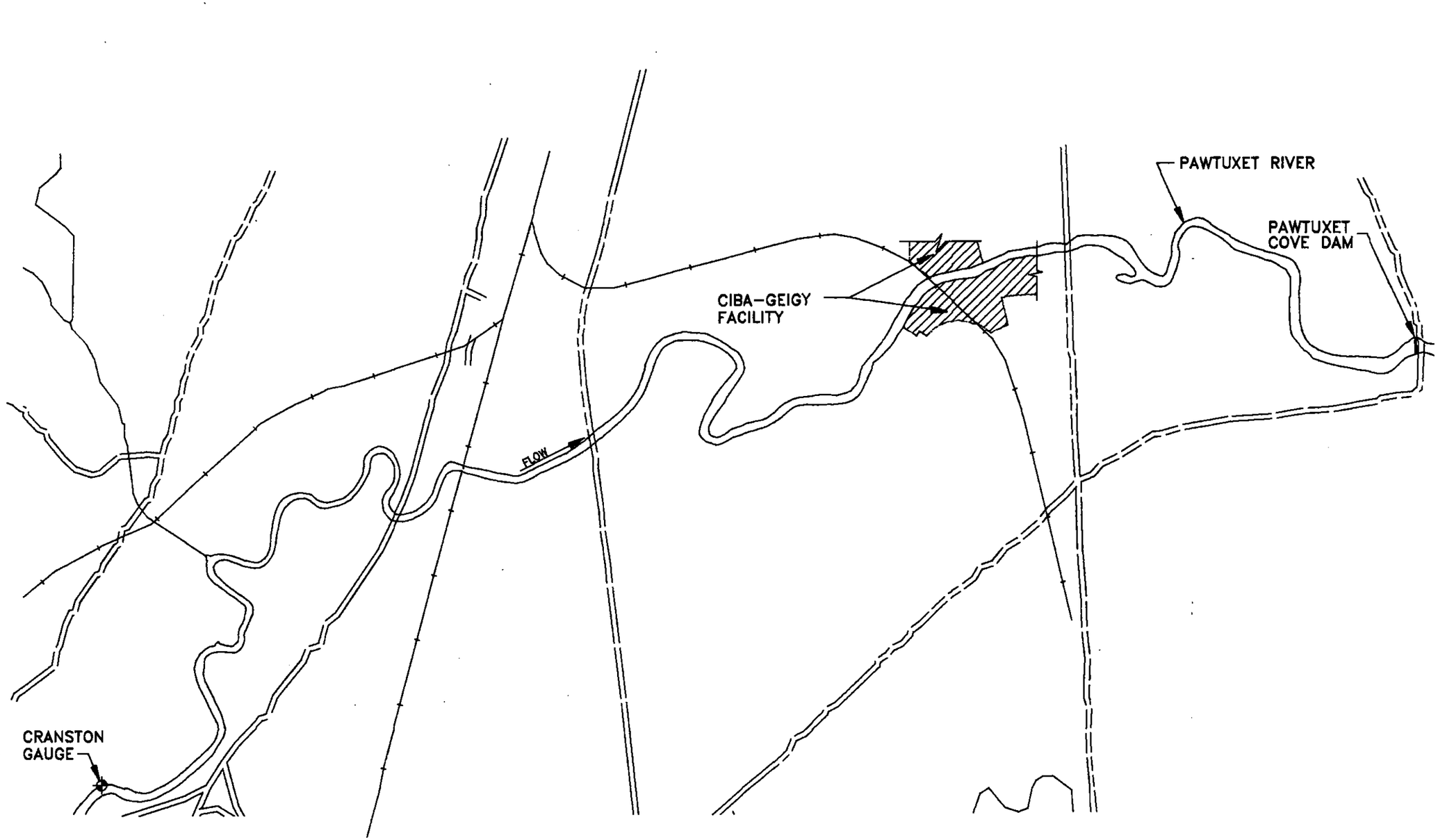
The bulk density/moisture content sample will be collected by removing a two-inch "slice" from the center of the sample core if a coring device was used to collect the sample; if a grab sampler (e.g., Ponar) was used, bulk density will not be measured. So far as possible, an undisturbed core sample will be collected. After the bulk density/moisture content sample has been collected, the remaining sediment will be homogenized by mixing in a stainless steel bowl until the sample is visually homogenous in color and texture; the particle size and TOC samples will be collected from the homogenized mixture. The sample analysis and quality assurance procedures to be used were described in the Quality Assurance Documents, Volume 2 of the RCRA Facility Investigation Proposal.

4.5.3 Measuring Stage Height

Stage height measurements will be taken at a location in the facility reach. A pressure transducer with a data logger will be installed at a convenient location near the former cofferdam. Ideally, the pressure transducer will be in operation from late February (or early March) until the end of June. A stage height measurement will be made automatically once every two hours during this period. These data, coupled with stage data collected at the USGS Cranston gauge, will be used for calibrating and verifying the hydrodynamic model. The data collected during this period

should span three different flow regimes — low flow (100 to 500 cubic feet per second, or cfs), medium flow (500 to 1000 cfs), and high flow (greater than 1000 cfs).

In the hydrodynamic model, the stage height at the Pawtuxet Cove Dam (the downstream boundary of the model) is needed as an input. A stage-discharge curve, similar to the existing one



SCALE: 1 INCH=1200 FEET

1200' 0 1200'

PHASE II PAWTUXET
RIVER INVESTIGATION
STUDY AREA

WOODWARD-CLYDE CONSULTANTS

CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS
WAYNE, NEW JERSEY

DR.BY	GT	SCALE	1" = 1200'	PROJ.	87X4660
CK'D.BY	JR	DATE	SEPT 29, 1993	FIG.NO.	4-1

File name: J:\C400\87X4660\7.DWG Last edited: 93/10/29 @ 08:34

- Total petroleum hydrocarbon (TPH) concentrations ranged from not detected to 33,000 ppm; total polycyclic aromatic hydrocarbon (TPAH) concentrations ranged from 0.290 to 167.7 ppm.

- Roughly equal amounts of many polycyclic aromatic hydrocarbons (PAHs) were present in most of the samples (regardless of the total PAH concentration), except that naphthalene comprised a high percentage of the TPAH in two samples collected at the location of the former cofferdam.

- TPH and TPAH concentrations were lowest in the river channel, higher on the riverbank, and higher still at the location of the former cofferdam.

Sediment samples were collected at seven transects in the facility reach. The samples collected at transects TR-02 and TR-03 (which bound the river between the upstream and downstream boundaries of the Production Area) contained the highest concentrations of contaminants. The concentrations of contaminants varied over a wide range; the highest concentrations were detected in the samples collected near the bulkhead. For the purposes of the Phase II release characterization, the section of the river within the boundaries of the Production Area is considered to be a source area. This area is about 400 feet long and about 125 feet wide. Further vertical delineation of the source area is required for the Corrective Measures Study (CMS).

Because of these results, the facility reach has been sub-divided for the Phase II investigation into upper and lower portions. The *upper facility reach* extends from the upstream boundary of the facility reach to the downstream boundary of the Production Area (about 400 feet). The *lower facility reach* extends from the downstream boundary of the Production Area to the downstream boundary of the facility reach (about 1500 feet).

5.3.2 Data Gaps Identified in the Facility Reach

The Phase I release characterization identified two data gaps in the facility reach:

- The vertical extent of sediment contamination along the upper facility reach (adjacent to the Production Area) needs to be delineated.

- The horizontal and vertical extent of sediment contamination along the lower (i.e., remaining length of the) facility reach needs to be delineated.

5.3.3 Strategy for the Phase II Release Characterization in the Facility Reach

The strategy to fill the facility reach data gaps is:

- Establish transects to grid the upper facility reach for stratified sampling.

- Establish transects in the lower facility reach based on the results of the sediment mapping (from the Phase II hydrological investigation).

- Identify sediment sampling locations on the transects in both the upper and lower facility reaches.

- Collect and analyze sediment samples from the upper and lower facility reaches for selected analytes agreed on with the USEPA (and listed in Table 5-3).

5.3.4 Methods and Analyses for the Phase II Release Characterization in the Facility Reach

This section provides details on the sampling methodology and analyses to be used in the Phase II release characterization of the facility reach. Table 5-2 summarizes the sampling design for the Phase II Pawtuxet River release characterization.

Establishing Transects in the Facility Reach

Transects will be established in both the upper and lower portions of the facility reach.

Upper Facility Reach

Nine transects, spaced at 50-foot intervals, will be established in the upper facility reach. These transect locations, shown in Figure 5-1, will grid the reach in one dimension for stratified sampling. Each transect location will be marked with a surveyed stake on each bank of the river.

Lower Facility Reach

Twelve transects will be established in the lower facility reach (based on the sediment mapping results from the Phase II hydrological investigation) in areas where cohesive/high-TOC sediments are present. Each transect location will be marked with a surveyed stake on each bank of the river.

Identifying Sediment Sampling Locations

Sampling locations will be identified on the transects in both the upper and lower portions of the facility reach.

Upper Facility Reach

Five potential sampling locations, spaced about 30 feet apart, will be identified on each of the nine transects in the upper facility reach. First, two sampling locations, each about 5 feet from a river bank, will be identified on each transect. Next, the other three sampling locations on each transect will be positioned so as to be equally spaced between the outer two sampling locations (as shown in Figure 5-1). These 45 (total) potential sampling locations (five on each of nine transects) complete the horizontal grid needed for the stratified sampling in the upper facility reach. In Round 1, twenty-seven locations will be sampled — three locations (selected randomly out of the five potential locations) will be sampled on each of the nine transects. If necessary, the sampling locations will be adjusted (minimally) in the field. Before sampling at a location, the sediment will be probed manually using a pointed, incremented range pole to verify the sediment mapping results. The exact position of each sampling location will be verified using an EDMI device or a metered tape. No sediment samples will be collected in Round 2 from the upper facility reach because this reach will have been sampled extensively in Round 1.

Lower Facility Reach

Two sampling locations will be identified on each of the twelve transects in the lower facility reach. The 24 sampling locations will be positioned where cohesive/high-TOC sediments are found (based on the sediment mapping). If necessary, the sampling locations will be adjusted in the field. Before sampling at a location, the sediment will be probed manually using a pointed, incremented range pole to verify the sediment mapping results. The exact position of each sampling location will be verified using an EDMI device or a metered tape.

Two rounds of sampling will be performed. In Round 1, 24 samples (two on each of the twelve transects) will be collected. The vertical extent of contamination in the lower facility reach will not be evaluated until the horizontal extent of contamination is determined by the results from Round 1 sampling. If contamination is detected in the lower facility reach from the Round 1 analytical results, the vertical extent of contamination in the lower facility reach will be evaluated in Round 2. If no contamination is detected in the lower facility reach in Round 1, evaluating the vertical extent of contamination in the lower facility reach will not be warranted.

In Round 2, a total of twelve samples will be collected. Three of the Round 1 (surficial) sampling locations (selected based on the Round 1 analytical results) will be resampled in Round 2 to verify the Round 1 results. Nine other Round 2 samples will be collected at locations selected after reviewing the Round 1 analytical results. Depending on the nature and extent of contamination detected in the Round 1 surficial samples, some or all of these other nine Round 2 samples:

- may be collected with depth at Round 1 locations to evaluate the vertical extent of contamination in the lower facility reach; or
- may be collected surficially at locations not sampled in Round 1 to characterize more completely the horizontal extent of contamination in the lower facility reach.

Collecting and Analyzing Sediment Samples

Samples will be collected and analyzed at the sampling locations in both the upper and lower portions of the facility reach.

Upper Facility Reach

Sediment samples will be collected using a boat-mounted rig (e.g., Vibracore® system). An attempt will be made to collect two samples at each sampling location selected — one shallow (at a depth of 1 to 2 feet) and the other deep (at 3 to 4 feet). At sampling locations where the sediment is less than 4 feet thick, the deeper sample will be collected down to the point of refusal, with the condition that the sediment be at least 2.5 feet thick. At locations where the sediment is less than 2.5 feet thick, a deep sample will not be collected. No surfical samples will be collected in Phase II because the surficial sediment was characterized adequately in Phase I.

In Round 1, twenty-seven locations (selected randomly) will be sampled. At each sampling location, one or two samples will be collected (depending on the sediment depth), so the total number of samples could range from 27 to 54. Based on volume requirements for analysis, multiple samples may be needed. If so, the samples will be collected adjacent to one another at each location (as necessary).

After sediment has been placed in the volatile organic vials, the remaining sediment will be homogenized (by mixing in a stainless steel bowl until the sample is visually homogenous in color and texture) before filling the other sampling jars. All samples will be analyzed for those analytes listed in Table 5-3.

Lower Facility Reach

In Round 1, 24 surficial sediment samples will be collected using remote sampling devices (i.e., corers or Ponars) or hand-held corers, depending on the depth of the water. At each sampling location, samples will be collected to a depth of six inches (or to the penetration depth of the sampler). Based on volume requirements for analysis, multiple samples may be needed (depending on the type of sampling method used). If so, the samples will be collected adjacent to one another at each location (as necessary).

In Round 2, 12 more samples will be collected. Round 2 surficial samples will be collected using the same methods as for Round 1; Round 2 samples with depth (if any) will be collected using remote coring devices.

After sediment has been placed in the volatile organic vials, the remaining sediment will be homogenized (by mixing in a stainless steel bowl until the sample is visually homogenous in color and texture) before filling the other sampling jars. All 36 (i.e., 24 Round 1 and 12 Round 2) samples will be analyzed for those analytes listed in Table 5-3.

5.4 DOWNSTREAM REACH

This section summarizes the results from, and the data gaps identified in, the Phase I release characterization of the downstream reach. The downstream reach extends from the downstream boundary of the facility to a meander bend near Rhodes-on-the-Pawtuxet (as shown in Figure 2-2).

5.4.1 Summary of the Phase I Results for the Downstream Reach

The Phase I release characterization investigated both surface water and sediment in the upstream reach; the Phase I analytical and bioassay results are summarized here for sediment only.

Sediment (Analytical). The following analytical results were obtained for the seven sediment samples from the downstream reach.

Fraction	Number of Analytes Detected	Minimum and Maximum Detected Concentrations (ppm)	Range of Total Concentr'ns (ppm)	Mean Total Concentr'n (ppm)	Med'n Total Concentr'n (ppm)
VOCs	0 – 4	0.052 – 0.2	ND – 0.4	0.13	ND
Semi-Volatiles	5 – 15	0.044 – 4.1	1.8 – 15.1	8.14	7.2
PCBs	0 – 0	—	—	—	—
Dioxins/Furans	0 – 0	—	—	—	—
Pesticides/Herbicides	0 – 7	0.0014 – 0.043	ND – 0.138	0.033	0.022
Metals/Cyanide	The following exceeded baselines: calcium (1), chromium (1), copper (1), manganese (1), mercury (1)				

Sediment (Bioassay). Survival of *C. dubia* in pore water from Round 1 downstream sediment samples did not differ significantly from survival in laboratory control and upstream samples. However, survival of *C. tentans* larvae in Round 1 downstream sediment samples was significantly lower than survival in the far upstream sediment sample; survival in the far downstream sediment sample also was significantly lower than survival in the reference sediment and in the near upstream sample. In Round 2, survival was lower in all the samples than in the reference sediment, but survival in sample SD-13R did not differ from survival in the upstream samples.

5.4.2 Data Gaps Identified in the Downstream Reach

The Phase I release characterization identified two data gaps in the downstream reach:

- The horizontal and vertical extent of sediment contamination originating from the facility needs to be delineated.

- The factors influencing contaminant movement in the river need to be evaluated more completely.

5.4.3 Strategy for the Phase II Release Characterization in the Downstream Reach

The strategy to fill the downstream reach data gaps is:

- Establish transects in the downstream reach based on the results of the sediment mapping (in the Phase II hydrological investigation).
- Identify sampling locations based on the results of the sediment mapping.
- Collect and analyze sediment samples for those analytes listed in Table 5-3.
- Identify the contribution of constituents to the observed toxicity in order to discriminate site-related effects.
- Develop a chemical fate model of the river that, coupled with the hydrodynamic and sediment transport models (discussed in Appendix E), can be used to simulate contaminant transport and fate in the river.

5.4.4 Methods and Analyses for the Phase II Release Characterization in the Downstream Reach

This section provides details on the sampling methodology and analyses to be used in the Phase II release characterization of the downstream reach. Table 5-2 summarizes the sampling design for the Phase II Pawtuxet River release characterization.

Establishing Transects in the Downstream Reach

In the downstream reach, four transects will be established in areas where cohesive/ high-TOC sediments are present (based on the sediment map). Each transect location will be marked with a surveyed stake on each bank of the river.

The data available do not warrant extending the investigation further downstream than Rhodes-on-the-Pawtuxet. In Phase I, aquatic toxicity bioassays on river sediments showed high toxicity for sediments from the facility reach and from Rhodes-on-the-Pawtuxet. However, sediments from the area between those two locations were less toxic. In fact, sediment bioassay results at one location did not differ appreciably from those obtained upstream of the site. The Phase I analytical (chemical) results for sediment samples from the facility reach and Rhodes-on-the-Pawtuxet were very different (both qualitatively and quantitatively) as shown in Tables 3-6, 3-7, 3-9, and 3-10. Taken together, these bioassay and analytical results suggest that different constituents and different sources may account for the aquatic toxicity observed for sediments from these two locations.

Because these data are not conclusive, additional information is needed before extending the investigation further downstream is justified. The sediment mapping, sediment release characterization, toxicity identification evaluations (discussed in Chapter 6), and contaminant transport and fate modeling (discussed in Appendix E) proposed for Phase II are designed to delineate the nature and extent of site-related impacts on the Pawtuxet River. This information will be used to

determine whether there is a need to extend the area of the river investigated. If warranted by the Round 1 analytical results in Phase II, additional samples will be collected downstream of Rhodes-on-the-Pawtuxet in Round 2.

Identifying Sediment Sampling Locations

Two sampling locations will be identified on each of the four transects in the downstream reach. The eight sampling locations will be positioned in areas where cohesive/high-TOC sediments are found. If necessary, the sampling locations will be adjusted in the field. Before sampling at a location, the sediment will be probed manually using a pointed, incremented range pole to verify the sediment mapping results. The exact position of each sampling location will be determined using an EDMI device or a metered tape.

Two rounds of sampling will be performed. In Round 1, eight samples (two on each of the four transects) will be collected. In Round 2, eight more samples will be collected. Two of the Round 1 (surficial) sampling locations (selected based on the analytical results) will be re-sampled in Round 2 to verify the Round 1 results. Six other Round 2 samples will be collected at locations selected after reviewing the Round 1 analytical results. Depending on the nature and extent of contamination detected in the Round 1 surficial samples, some or all of these other six Round 2 samples:

- may be collected with depth at Round 1 locations to evaluate the vertical extent of contamination in the downstream reach; or
- may be collected surficially at locations not sampled in Round 1 to characterize more completely the horizontal extent of contamination in the downstream reach.

Collecting and Analyzing Sediment Samples

In Round 1, 8 surficial sediment samples will be collected using remote sampling devices (i.e., corers or Ponars) or hand-held corers, depending on the depth of the water. At each sampling location, samples will be collected to a depth of six inches (or to the penetration depth of the sampler). Based on volume requirements for analysis, multiple samples may be needed (depending on the type of sampling method used). If so, the samples will be collected adjacent to one another at each location (as necessary).

In Round 2, 8 more samples will be collected. Round 2 surficial samples will be collected using the same methods as for Round 1; Round 2 samples with depth (if any) will be collected using remote coring devices.

After sediment has been placed in the volatile organic vials, the remaining sediment will be homogenized (by mixing in a stainless steel bowl until the sample is visually homogenous in color and texture) before filling the other sampling jars. All 16 (i.e., 8 Round 1 and 8 Round 2) samples will be analyzed for those analytes listed in Table 5-3.

Identifying the Contribution of Constituents to Toxicity

Details about the methods and analyses proposed for identifying the contribution of constituents to the observed toxicity are presented in Chapter 6 of this document.

Developing a Chemical Fate Model

Details about the methods and analyses proposed for developing the chemical fate model are presented in Appendix E of this document.

5.5 CONSIDERATIONS FOR THE PHASE II PAWTUXET RIVER RELEASE CHARACTERIZATION

Other considerations for the Phase II Pawtuxet River release characterization — including integration of the data with other Phase II studies as well as contingencies for the Phase II Pawtuxet River release characterization — are discussed here.

Integration with Other Phase II Studies

The data from the Phase II Pawtuxet River release characterization will be compared with the data from the Phase I release characterization to delineate more fully the nature and extent of sediment contamination. These release characterization data, when linked with the information from the (Phase I and II) physical characterizations, will provide the basis for the Public Health and Environmental Risk Evaluation (PHERE) study. Integrating the data from all three investigations (i.e., physical characterizations, release characterizations, and PHERE) will provide the information needed for proposing Media Protection Standards (MPS) and developing a strategy for the Corrective Measures Study (CMS).

Contingencies for the Phase II Pawtuxet River Release Characterization

There are no contingencies for the activities proposed in the Phase II Pawtuxet River release characterization.

5.6 SUMMARY

The Phase II Pawtuxet River release characterization will delineate the vertical extent of the source of contaminated sediments along the Production Area in the facility reach as well as the horizontal extent of contamination in all three reaches. The strategy for delineating contamination in all three reaches involves establishing transects, identifying sediment sampling locations, and collecting and analyzing sediment samples for selected analytes. Most of the locations for transects and samples will be based on the sediment mapping results from the Phase II hydrological investigation; some locations will be determined by a stratified sampling plan:

- In the *upstream* (background) reach, 2 locations will be sampled on each of 4 transects (positioned based on the sediment map) in Round 1; 8 more locations (2 for verification) will be sampled in Round 2 (at locations to be determining after reviewing the Round 1 results). All 16 samples will be tested for Appendix IX analytes.

- In the *upper facility* reach, 3 locations (selected randomly) will be sampled on each of 9 (equally spaced) transects; a shallow and (if possible) a deep core will be collected at each location. (Deep cores will not be collected where the sediment is less than 2.5 feet thick.) In Round 1, all samples (potentially ranging from 27 to 54) will be tested for those analytes listed in Table 5-3. No sediment samples will be collected in Round 2 from the upper facility reach because this reach will have been sampled extensively in Round 1.

- In the *lower facility* reach, 2 locations will be sampled on each of 12 transects (positioned based on the sediment map) in Round 1; 12 more locations (3 for verification) will be sampled in Round 2 (at locations to be determining after reviewing the Round 1 results). All 36 samples will be tested for those analytes listed in Table 5-3.

- In the *downstream* reach, 2 locations will be sampled on each of 4 transects (positioned based on the sediment map) in Round 1; 8 more locations (2 for verification) will be sampled in Round 2 (at locations to be determining after reviewing the Round 1 results). All 16 samples will be tested for those analytes listed in Table 5-3.

The constituents contributing to the observed toxicity downstream will be identified in order to discriminate site-related effects. Finally, a chemical fate model will be developed and will be coupled with the hydrodynamic and sediment transport models to simulate contaminant transport and fate in the river. The Phase II release characterization data will be compared with the Phase I data to delineate the nature and extent of sediment contamination. Integrating the release and physical characterization data will support the PHERE; integrating all these data will support the MPS Proposal and the CMS Proposal for the river. The next chapter presents the proposal for the Phase II environmental (PHERE-related) assessment.

Table 5-1. Outline of the Phase II Pawtuxet River Release Characterization Proposal

Location	Data Gaps/Needs	Strategy	Activities Proposed	Contingency
Upstream Reach	Sediment not fully characterized	Establish transects	4 transects based on sediment mapping cohesive/high-TOC sediment areas or downstream of input sources	
		Identify sedim. sampling loc'ns	8 sampling locations (2/transect) based on sediment mapping cohesive/high-TOC sediment areas or downstream of input sources	
		Collect & analyze samples	in Round 1: collect 8 surficial samples 1 at each location analyze 8 Round 1 samples for App IX in Round 2: collect 8 surficial samples 2 at Round 1 locations based on analytical results to verify Round 1 results 6 at locations not in Round 1 to delineate horizontal extent more analyze 8 Round 2 samples for App IX	
Facility Reach	Delineate vert sedim. near bulkhead	Establish transects	9 transects in upper facility reach @ 50-ft intervals to grid upper reach horizontally	
		Identify sedim. sampling loc'ns	45 potential locations (5/transect) 2/transect near riverbank 3/transect spaced equally randomly select 3 loc'ns/transect for a total of 27 sampling locations	
		Collect & analyze samples	attempt to collect 2 cores/location one shallow (1–2 ft) one deep (3–4 ft) no deep sample if sediment < 2.5 ft analyze (27–54) samples for selected analytes agreed on with USEPA	
	Delineate horiz & vert sedim in rest	Establish transects	12 transects in lower facility reach based on sediment mapping cohesive/high-TOC sediment areas	
		Identify sedim. sampling loc'ns	24 sampling locations (2/transect) based on sediment mapping cohesive/high-TOC sediment areas	
		Collect & analyze samples	in Round 1: collect 24 surficial samples 1 at each location analyze 24 Round 1 samples for selected analytes agreed on with USEPA in Round 2: collect 12 surficial samples 3 at Round 1 (surficial) locations based on Round 1 analytical results to verify Round 1 results 9 at other locations based on Round 1 analytical results some may be deep —at locations sampled in Round 1 —to delineate vertical extent some may be surficial —at locations not sampled in Round 1 —to delineate horizontal extent more analyze 12 Round 2 samples for selected analytes agreed on with USEPA	

Table 5-1. Outline of the Phase II Pawtuxet River Release Characterization Proposal (continued)

Location	Data Gaps/Needs	Strategy	Activities Proposed	Contingency
Downstream Reach	Delin. horiz & vert contam'n from site	Establish transects	4 transects based on sediment mapping cohesive/high-TOC sediment areas	
		Identify sedim. sampling loc'ns	8 sampling locations (2/transect) based on sediment mapping cohesive/high-TOC sediment areas	
		Collect & analyze samples	in Round 1: collect 8 surficial samples 1 at each location analyze 8 Round 1 samples for selected analytes agreed on with USEPA in Round 2: collect 8 samples 2 surficial at Round 1 locations based on Round 1 analytical results to verify Round 1 results 6 at other locations based on Round 1 analytical results some may be deep —at locations sampled in Round 1 —to delineate vertical extent some may be surficial —at locations not sampled in Round 1 —to delineate horizontal extent more analyze 8 Round 2 samples for selected analytes agreed on with USEPA	
		Identify contributors to toxicity	*[These activities are discussed in Chapter 6.]*	
	Evaluate factors in contam movement	Develop chemical fate model	*[These activities are discussed in Appendix E.]*	

Table 5-2. Proposed Phase II Pawtuxet River Release Characterization Sampling Program

Reach	# of Transects	# Samples/ Transect	# Depths Sampled	Total # Samples	Analytes	Sediment Sample Type
Upstream Reach						
Round 1:	4	2	1	8	App. IX	surficial
Round 2:	TBD	TBD	1	8	App. IX	surficial
Facility Reach						
Upper Facility Reach	9	3	1-2	27-54	*	at depth
Lower Facility Reach						
Round 1:	12	2	1	24	*	surficial
Round 2:	TBD	TBD	TBD	12	*	TBD
Downstream Reach						
Round 1:	4	2	1	8	*	surficial
Round 2:	TBD	TBD	TBD	8	*	TBD

* Selected analytes agreed on with the USEPA (see Table 5-3).
TBD To be determined based on the Round 1 analytical results.

Table 5-3. Analytes for Phase II Pawtuxet River Sediment Release Characterization

PCBs
Chlorobenzene
Toluene
Naphthalene
bis(2-ethylhexyl)phthalate
Tinuvin 328
Arsenic
Copper
Lead
Silver
Zinc

In Round 1, one sediment sample from each transect in the facility reach and the downstream reach (established for the release characterization) will be analyzed for Appendix IX Dioxins/Furans. In Round 2, verification sampling will be performed only at Round 1 locations in which Dioxins/Furans were detected.

All sediment samples from transects in the upstream reach will be analyzed for Appendix IX compounds.

OLD CH. 6

TEXT

FOLLOWS

6.0 PHASE II ENVIRONMENTAL ASSESSMENT PROPOSAL

6.1 OVERVIEW

This chapter proposes a work plan for the Phase II environmental assessment of the Pawtuxet River as part of the Public Health and Environmental Risk Evaluation (PHERE) in the RCRA Facility Investigation of the CIBA-GEIGY facility at Cranston, Rhode Island. The environmental assessment work plan has been prepared in accordance with current USEPA guidance. However, the procedures for environmental risk assessments are not as well defined as are those for human health risk assessment. The current scientific literature is not adequate to address most individual endpoints. The database is inadequately defined as compared to that for human health risk assessments. The following documents, specifically applicable to ecological assessments, guided the development of this work plan:

- *Supplemental Risk Assessment Guidance for the Superfund Program* (USEPA Region I, 1989);
- *Risk Assessment Guidance for Superfund, Volume II: Environmental Evaluation Manual* (USEPA, 1989);
- *Ecological Assessments of Hazardous Waste Sites: A field and laboratory reference document* (USEPA, 1989b);
- *Sediment Toxicity Evaluation: Phase I, Phase II, and Phase III Modification of Effluent Procedures* (USEPA, 1991);
- *Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents* (USEPA, 1973); and
- *1991 Annual Book of ASTM Standards* (ASTM, 1991).

The Phase II ecological assessment is structured according to the general overview of ecological assessments provided by USEPA Region I (1989) and presented in Figure 6-1. The structure of the site-specific ecological assessment is presented in Figure 6-2 and has six tasks:

- *Task 1* — Toxicity Identification Evaluations;
- *Task 2* — Literature Review;
- *Task 3* — Aquatic Environment Investigations;
- *Task 4* — Terrestrial Environment Investigations;
- *Task 5* — Ecological Assessment of the Pawtuxet River; and
- *Task 6* — Ecological Assessment of the facility.

Non-riparian (i.e., non-riverbank-dwelling) terrestrial investigations (part of Task 4) and the ecological assessment of the CIBA-GEIGY facility (Task 6) are not discussed in this document.

In the Phase II environmental assessment, interrelated investigations will be performed to:

- characterize the biota of the area;
- identify potential sources of impact to the biota attributable to the facility;
- identify receptor populations;
- assess exposure; and
- characterize risk to the environmental receptors.

At the conclusion of the Phase II biological investigations (Tasks 3 and 4), the results from the Phase II hydrological investigation (discussed in Chapter 4) and the Phase II Pawtuxet River release characterization (discussed in Chapter 5) will be incorporated into Tasks 5 and 6 of the Phase II environmental assessment to assess the risk to the environment from site-related contaminants in the Pawtuxet River.

Table 6-1 outlines the work proposed for the Phase II environmental assessment of the Pawtuxet River, including:

- the *data gaps* identified in Phase I (or other *data needs* for Phase II);
- the *strategies* proposed to fill those data gaps or needs;
- the *activities* proposed to implement those strategies; and
- any *contingencies* that could impact the activities proposed.

This chapter is organized around Table 6-1. Section 6.2 of this chapter briefly reviews the results from the Phase I investigations. Section 6.3 presents the data gaps/needs identified from Phase I. Section 6.4 outlines the strategies proposed for the Phase II environmental assessment of the Pawtuxet River and Section 6.5 presents the methods and analyses proposed for implementing those strategies. Finally, Section 6.6 discusses other considerations for the Phase II environmental assessment, including integrating the data with other Phase II studies and contingencies for the activities proposed. The chapter concludes with an overall summary in Section 6.7.

6.2 PHASE I RESULTS FOR THE PAWTUXET RIVER

This section summarizes the Phase I investigations involving the Pawtuxet River — the hydrological investigation (part of the physical characterization of the site) and the Pawtuxet River release characterization. Detailed discussions of these results were presented in Chapters 2 and 3 of this document.

6.2.1 Phase I Hydrological Investigation

The Phase I hydrological investigation was undertaken along the facility reach and included a literature review, a bathymetry survey, a water discharge survey, suspended sediment discharge monitoring, and a riverbed sediment characterization. The overall goal of the hydrological investigation was to evaluate the physicochemical characteristics of the river with respect to the storage and/or transport of constituents of concern.

The Pawtuxet River has received discharges (in both the past and present) from many industries as well as from several sewage treatment plants. Dating back to the 1700s, forges and textile mills discharged to the Pawtuxet River; privies serving up to 3000 employees were positioned directly over the river. Currently, the waste water treatment plants of the Warwick, West Warwick, and Cranston municipalities, as well as industrial metal platers and jewelry manufacturers, are upstream of the facility.

Water depth ranged from 2 to 9 feet along the facility reach during the bathymetric investigation on 23 July 1990. Pools may have been caused by previous dredging activities or by erosional processes in the river. In general, shallow areas are colonized by aquatic macrophytes. These weed beds may simultaneously cause sediment deposition by creating a baffling effect and prevent erosion by stabilizing the sediment-water interface.

6.2.2 Phase I Pawtuxet River Release Characterization

The Phase I release characterization investigated the upstream reach of the Pawtuxet River as a background location, and investigated both the facility and downstream reaches to evaluate the potential impact (if any) of past discharges. Two media of concern, surface water and riverbed sediment, were investigated in each reach; two sampling rounds were conducted on each medium in each reach. In general, the objectives of the Phase I Pawtuxet River release characterization included determining the nature of contamination in Pawtuxet River surface water and sediments, as well as determining if releases from the facility are impacting surface water quality and/or sediments in the river. Chemical analyses of samples, and bioassay tests of organisms exposed to samples, were conducted.

The surface water analytical results were comparable across all three reaches. In general, the same organic analytes tended to be detected in all three reaches, and no PCBs, dioxins, or furans were detected in any samples. A limited number of analytes, and small ranges of concentrations, were detected across all three reaches. This comparability across reaches is

to be expected since the river is a very dynamic system and river flow typically is well-mixed from turbulent flow.

The sediment analytical results indicated that the nature of contamination in the facility reach sediments are more extensive than anticipated and are not fully understood. Release characterization sampling and contaminant transport and fate modeling proposed for Phase II will provide information on the temporal and spatial distribution of contaminants.

The Phase I bioassay results indicated no toxicity in the surface waters of the Pawtuxet River in the region of the facility, but indicated toxicity in the river sediments. Sediments sampled from 18 locations (3 upstream, 10 in the facility reach, and 5 downstream) were tested for toxicity. Toxicity was detected in sediments and interstitial waters throughout the facility reach and, to varying degrees, downstream of the site. The most sensitive organism for detecting this toxicity was the larvae of the midge, *Chironomus tentans*. Sediments with the highest toxicity were encountered adjacent to the Production Area; toxicity generally decreased downstream, except that toxicity increased in sediments sampled about 1.5 miles downstream from the site. Currently, there is no explanation for the increased toxicity downstream.

6.2.3 Ecological Habitat Description

The site is located in the Pawtuxet River Basin, encompassing an area of about 230 square miles (Metcalf and Eddy, 1983). The Pawtuxet River, which separates the Production and Waste Water Treatment areas from the Warwick Area, is the only surface water body topographically downgradient of the site. Flow in the Pawtuxet River is regulated by two reservoir dams (Scituate Reservoir and Flat Rock Reservoir), the Pawtuxet Cove Dam, and multiple small mill dams throughout the length of the river. The watershed includes rural, urban, and industrial land uses. Woodlands, wetlands, and grasslands exist in the reach of the river investigated. The state of Rhode Island has described the present water quality conditions in the Pawtuxet River as Class D downstream of the Cranston Sewage Treatment

Plant; the facility reach is located within this area. Class D waters are suitable for migration of fish and have good aesthetic value, but are not suitable for public water supply, agriculture, swimming, boating, or fish and wildlife habitat.

6.3 PHASE I DATA GAPS / PHASE II DATA NEEDS

The Phase I data gaps/Phase II data needs for the Phase II hydrological investigation and Pawtuxet River release characterization were presented in Chapters 4 and 5. Seven data gaps/data needs were identified for the Phase II environmental assessment:

- An ecological characterization of the upstream reach, including basic water quality data and an inventory of biota, is needed to establish baseline conditions.

- Characterization of the biota is needed to determine whether the ecotoxicological effects identified in Phase I have had an impact on the community.

- The vicinity of the site contains a variety of suitable habitats (e.g., woodlands, wetlands, and the river) for resident and migratory mammals, birds, and waterfowl; the identity of possible receptors of site-related constituents needs to be determined.

- The presence or absence of State- or Federally-designated threatened or endangered species or other sensitive natural resources needs to be ascertained.

- The exposure scenarios of the potential receptors to the constituents need to be identified.

- The risk of effects due to exposure needs to be characterized.

- The contribution of constituents to observed toxicity needs to be identified in order to discriminate site-related effects.

6.4 STRATEGY FOR THE PHASE II ENVIRONMENTAL ASSESSMENT

The strategy to fill these data gaps/data needs in the Phase II environmental assessment of the Pawtuxet River is based on the first five tasks shown in Figure 6-2:

- Conducting Toxicity Identification Evaluations (Task 1);
- Conducting a Literature Review (Task 2);
- Conducting Aquatic Environment Investigations (Task 3);
- Conducting Terrestrial Environment Investigations (Task 4); and
- Performing an Ecological Assessment of the Pawtuxet River (Task 5).

Conducting Toxicity Identification Evaluations (Task 1)

Toxicity Identification Evaluations (TIEs) will be conducted on sediments collected from a total of eight downstream and facility reach locations using procedures based on available USEPA guidelines. The TIEs will assist in describing sources of toxicity and delineating potential site-related impacts on the Pawtuxet River. TIEs are structured into four steps. All steps may not be performed based on necessity and practicality. These steps are:

1. Determining the most appropriate species-media pair.
2. Characterizing the chemical class(es) to which the toxicant(s) belong.
3. Characterizing some specific constituents within these classes.
4. Confirming the cause of toxicity (i.e., the toxicants identified), if necessary.

Conducting a Literature Review (Task 2)

A literature review will be conducted to evaluate existing data about the vicinity of the site and the river. Previous environmental studies provide general information on the ecology of the site, but site-specific data on biota will be collected during the Phase II environmental assessment. Several sources will be consulted as part of the literature review to identify

endangered species in the project area. The result of this effort will be a species list that will be used in screening-level risk assessments.

Conducting Aquatic Environment Investigations (Task 3)

Aquatic environment investigations will involve:

- Conducting a habitat characterization of the Pawtuxet River.
- Conducting a survey of the benthic communities in the Pawtuxet River and in the Waste Water Treatment Area pond.
- Conducting a survey of the fish populations in the Pawtuxet River and in the Waste Water Treatment Area pond.
- Based on the results of the aquatic surveys, assessing the impact of site-related constituents on the aquatic biota by comparing community indices (such as richness, evenness, and diversity as well as the presence/absence of tolerant/sensitive species).

Conducting Terrestrial Environment Investigations (Task 4)

Terrestrial environment investigations will involve:

- Site visit
- Conducting a screening-level risk assessment to evaluate potential effects on riparian (riverbank-associated) fauna as identified in the literature.
- Conducting surveys, if necessary, of riparian mammal, herptiles and bird populations.

The results from Task 4 will be integrated with the results from Task 3 and used to support Task 5. (Non-riparian terrestrial environment investigations are not discussed in this chapter.)

Performing an Ecological Assessment of the Pawtuxet River (Task 5)

The ecological assessment of the Pawtuxet River will involve:

- Identifying receptor populations based on the results from the biota surveys (in Tasks 3 and 4).
- Assessing the exposure of the ecosystem or biological populations at risk to the site-related constituents based on the results from the hydrological investigation, the Pawtuxet River release characterization, and the biological investigations.
- Evaluating the potential for particular constituents to cause increases in the incidence of particular effects.
- Characterizing potential biological effects based on the results from the field investigations, the exposure assessment, and the toxicity assessment.

6.5 METHODS AND ANALYSES FOR THE PHASE II ENVIRONMENTAL ASSESSMENT

This section provides details about the sampling methodology, analyses, and data evaluation to be used in the Phase II environmental assessment of the Pawtuxet River. The methods will describe and analyze the biotic and abiotic components of the existing ecosystem to determine the impacts associated with the potential release of contaminants. The analyses include characterizing the principal ecosystems in the area, determining which biological populations are at risk, characterizing contaminant profiles possibly associated with previously documented effects, and identifying exposure pathways to biological receptors. This section is organized around the five tasks in the Phase II environmental assessment of the Pawtuxet River.

6.5.1 Conducting Toxicity Identification Evaluations (Task 1)

In Phase I, bioassay tests conducted on sediments from the Pawtuxet River (discussed in Chapter 3) indicated toxicity to *Chironomus tentans* (midge) larvae in the facility reach and the "far downstream" reach. The extent of the area of impact related to the facility was not defined adequately by these bioassay tests. To determine if the toxicity observed in downstream samples is site-related, identification of the toxicant(s) responsible (or, at least, the general class of the toxicant — e.g., metals, volatile organics, non-polar organics) is highly desirable.

To reach this goal, toxicity identification evaluations (TIEs) will be performed on sediments collected from downstream locations as well as from selected facility reach locations sampled for toxicological and chemical analyses in the Phase I Pawtuxet River release characterization. (The locations that demonstrated high toxicity in Phase I testing will be selected for Phase II sampling.) A total of 8 locations will be sampled for the TIEs; the procedures will be based on USEPA guidelines available for sediment TIEs.

The TIEs will be performed in four steps (shown in Figure 6-3):

1. Determining the most appropriate species-media pair.
2. Characterizing the chemical class(es) to which the toxicant(s) belong.
3. Characterizing some specific constituents within these classes.
4. Confirming the cause of toxicity (i.e., the toxicants identified), if necessary.

Sufficient sediment samples will be collected from each location using a Ponar grab sampler (following the same procedures used in Phase I, described in Appendix B). These samples will be stored on ice in the dark, transported to the aquatic toxicology laboratory, and stored in the dark at about 4°C.

Step 1: Determining the Appropriate Media-Species Pair

The first step of the TIEs is to determine the most appropriate medium and species to use. TIEs originally were designed for the investigation of municipal and industrial waste waters. These procedures cannot be adopted for bulk sediments, so either pore waters or elutriates must be used. Pore waters have been shown to have some applicability in predicting bulk sediment toxicity. Elutriates often have been used for determining toxicity due to resuspension of contaminants in the water column. Since toxicity of bulk sediments has been demonstrated already, these considerations are irrelevant. The aqueous medium that concentrates the toxicants most effectively will be identified and used for further chemical/physical manipulations and determinations in this study.

Species differ in sensitivity to different toxicants or classes of toxicants. Therefore, three different species will be tested in both pore water and elutriate for each sample and the species which is most sensitive to the toxicants present (as measured by an acute LC50) and the media in which it is most sensitive will be identified for each sample tested. Differing species sensitivities indicates different toxicants in samples. Juvenile fathead minnows (*Pimephales promelas*), neonate water fleas (*Ceriodaphnia dubia*), and midge larvae (*Chironomus tentans*) will be tested in both pore water and elutriates. *C. dubia* was tested in pore water bioassays during Phase I; however, a limited number of sediment samples was tested and effects were noted in only two of the six facility reach samples. *C. tentans* was the most sensitive species tested in Phase I sediments; however, bulk sediment (not pore water) was used in the bioassay; bulk sediment is not appropriate for TIE testing.

Furthermore, exposure of *C. tentans* to toxic constituents often is not related to pore water concentrations, so species-media sensitivity tests are essential for determining the most sensitive species-media pair to be used for further testing. Differences in species-media pairs between sampling locations can help delineate the area of impact related to the facility. If patterns of toxicity differ between locations so that a site-related zone of contamination can

be defined, then further testing may not be necessary. A sensitive practical species (instead of the most sensitive species) may be used for further testing if the patterns of toxicity between the two species are the same.

Step 2: Characterizing the Toxicant Chemical Classes

The class characterization step relies on the principles of chemistry to simplify and separate the toxicants and uses living organisms to track the toxicity. Each procedure used is designed to render a specific class of compounds unavailable to the organisms tested in the ensuing fraction of the sample. The reduction, enhancement, or lack of change in the toxicity of the fraction as compared to the original sample indicates the potential for a toxicant to be present from that class of constituents. The procedures and toxicity tests used during the characterization include:

- oxidant reduction tests using sodium thiosulfate (for oxidizers or reducers);
- EDTA chelation tests (for metals);
- aeration tests using pH adjustments (for volatile organics);
- C18 solid-phase (or other suitable) column extraction tests (for non-polar organics);
- filtration tests (for filterables); and
- graduated pH tests (for ammonia).

The results from the downstream reach will be compared with those from the facility reach. It is possible that this comparison will indicate the presence of different classes of toxicants in different samples, which may help define a site-related zone of contamination. These results will be used to determine which (if any) additional tests are needed to meet the delineation objective. Additional tests on complex samples intended to identify specific toxicants may not be possible.
If this is the case, the evaluation may stop here.

Step 3: Characterizing Specific Constituents in Classes

The objective of Step 3 is to identify the suspected toxicant(s). Some general guidance may be furnished by the outcome of Step 2, but usually both separation and concentration procedures will be needed to meet the objective. Often, C18 solid phase extraction, followed by methanol fractionation or high pressure liquid chromatography fractionation, followed by GC/MS analyses, is used. Identified constituent concentrations will be compared to concentrations in the scientific literature (if available) which have been shown to cause toxicity. The results from the downstream reach will be compared with those from the facility reach. If needed, testing will proceed to Step 4.

Step 4: Confirming the Cause of Toxicity

The confirmation step uses a group of procedures to confirm the suspected cause of toxicity. Rarely does one procedure or test conclusively prove the cause of toxicity; typically, all practical approaches are used to provide a "weight of evidence" that the cause of toxicity has been identified. The approaches that are often useful in providing such a "weight of evidence" are:

- correlation;
- observation of symptoms;
- relative sensitivity;
- spiking;
- mass balance estimates; and
- adjustments of water quality characteristics (such as pH and hardness) and measuring the resulting changes in toxicity.

The toxicants identified for each downstream site will be compared to each other and to the site-related contaminants in the facility reach to help identify the zone of site-related impacts, if needed.

6.5.2 Conducting a Literature Review (Task 2)

Site-specific data collected in Phase I (or earlier) will be used in the Phase II environmental assessment. Data available on aquatic and riparian environments and processes relating to the general vicinity of the site will be used. The Phase I investigation should provide most of the site-specific surface water and sediment data needed. Previous environmental studies provide general information on the ecology of the site, but site-specific data on biota will be collected during the Phase II environmental assessment.

Several sources will be consulted as part of the literature review to identify endangered species in the project area; these may include (but are not limited to):

- the Natural Heritage Program;
- Fish and Wildlife agencies;
- local college/university studies; and
- the available literature.

The result of the literature review will be a list of those species and habitat types likely to be present at the site. This will form a basis for activities performed in Tasks 3 and 4 and in the screening-level risk assessments.

6.5.3 Conducting Aquatic Environment Investigations (Task 3)

The aquatic investigations include:

- *habitat characterization; and*
- a *characterization of aquatic populations* (including a *fish population survey* and a *benthic macroinvertebrate survey*).

Based on the results of the above, the constituents and concentrations in the sediments, and predictions from hydrological modeling, the screening level risk assessment, including diversity analysis, will indicate whether a *species-specific fish survey* may be needed.

Habitat Characterization

The environmental risk evaluation will focus on the aquatic and riparian ecosystems of the Pawtuxet River in the region extending from the meander bend near Elmwood Avenue down to Rhodes-on-the-Pawtuxet. The facility reach and downstream reach may be a source of direct exposure of site-related constituents to resident fauna. The river upstream of the facility can serve as a reference area in evaluating less mobile fauna (e.g., benthos). The pond located in the Waste Water Treatment Area will also be included in this evaluation.

The habitat quality can be ascertained by characterizing the following parameters:

- flow characteristics;
- sedimentation characteristics;
- sediment grain size, organic content, and ammonia concentration;
- water quality parameters (i.e., biological and chemical oxygen demand, total dissolved and suspended solids, ammonia, nitrates/nitrites, total Kjeldahl nitrogen, phosphates, dissolved oxygen, pH, conductivity; and
- the availability of shelter, macrophytes, pools.

Sediment grain size, ammonia concentrations, and organic content will be collected during the benthic survey (discussed later). Information for the other parameters will be obtained from Phase I and additional Phase II studies. Although TOC and grain size will be measured during other field activities, the large variability of sediment and the need to correlate these data with the benthic community structure dictate these analyses. The additional water quality parameter measurements are needed to characterize the habitat and the quality of the

baseline ecosystem. Samples will be taken at eight locations in the river and pond during the fish and benthic surveys (Figure 6-4). Essentially, the river morphology and shelter availability (particularly aquatic macrophytes) are habitat descriptors. Physical observations will be made during all field surveys. Macrophyte species will be identified and mapped along the river during the fish and benthic surveys.

Forested upland, field, and wetland habitat occur along the Pawtuxet River study area. There is no evidence that these areas are directly affected by releases from the site. Species that feed in the river use these habitats as nesting and resting areas. Therefore, although the study will not address the terrestrial and wetland ecosystems specifically, these habitats will be characterized (physiognomy and dominant vegetation species association) and mapped to support interpretation of data concerning waterfowl and mammalian populations that rely on aquatic food resources.

Characterization of Aquatic Populations

A survey of the fish and macroinvertebrate communities in the Pawtuxet River and the pond in the Waste Water Treatment Area (WWTA) will be performed. Collection permits will be obtained from the appropriate authorities before field activities begin.

The results of the population surveys will be compared to information obtained in the literature review (Task 2) for the purpose of identifying state or federally listed threatened, endangered, sensitive or candidate species.

Fish Population Survey

A fish survey of the Pawtuxet River will be performed using a boat-mounted electroshocker for sample collection. The electroshocker unit (Smith-Root, Inc., Vancouver, WA) will be mounted on a 16-foot aluminum boat and will deliver 360 to 504 volts of direct current at 60 pulses per second. The duration of the electroshocking events will be recorded to

calculate catch-per-unit-effort. The survey of the WWTA pond will use a back-pack mounted electroshocker (Smith-Root Type VII Electrofisher).

Whenever applicable, captured fish will be held briefly for examination and recording of data, photographed, and then released. Age estimates of fish will be made in the field by an experienced fisheries biologist and will be based on length measurements and general condition.

Seven sampling transects in the Pawtuxet River and one in the WWTA pond will be used in the fish survey; these transects are shown in Figure 6-4. One reference transect in the river will be located far upstream of the facility (F-00), one just upstream of the facility (F-01), three in the facility reach (F-03, F-05, and F-07), and two downstream of the facility (F-13 and F-20). These transects will be observed sequentially. It is expected that the majority of fish species collected will be those having a relatively small home range, such as carp, members of the sucker family (Catostomidae), and members of the sunfish family (Centrarchidae). If the majority of species encountered are those having larger home ranges, consideration will be given to extending the distance between the transects and re-sampling. Transects should not be moved to the extent that interpretations of differences between fish populations from different transects becomes too speculative.

Data collected in the survey will include species identification, species enumeration, length, weight, and any deformities, skin lesions, or other abnormalities observed. The physical characteristics of the sample collection location also will be recorded. At a minimum, information will be collected as to water depth, current velocity, bottom substrate composition, and amount of available cover, including both terrestrial vegetation (shade) and aquatic macrophytes.

This survey will:

- evaluate impairment in the vicinity of the site as indicated by differences in populations throughout the river and by comparison to potential baseline communities;
- provide information on the food web in the vicinity of the site; and
- identify populations at risk under current conditions or potentially at risk under remedial measures.

Benthic Macroinvertebrate Survey

Benthic macroinvertebrates inhabiting riverine sediments include insects, annelids, mollusks, flatworms, and crustaceans that may be herbivores, carnivores, or omnivores. (In a well-balanced system, it is likely that all three types will be present). Trophic levels include deposit and detritus feeders, parasites, scavengers, grazers, and predators. As a result, these organisms are important members of the food web, and their health is reflected in the health of the higher forms (e.g., fish). Because the macroinvertebrate community in an aquatic ecosystem is very sensitive to stress, the community is a useful tool for detecting environmental perturbations from contaminants or naturally occurring stressors.

The benthic survey locations will be the 17 locations (SD-00M, SD-00L, SD-01R, SD-02R, SD-02L, SD-03R, SD-04R, SD-05M, SD-05L, SD-06R, SD-07L, SD-08M, SD-09R, SD-10M, SD-13R, SD-16L, and SD-20M) sampled for the Phase I sediment bioassays (shown in Figures 3-5 and 3-9). Two additional locations will be sampled in the WWTA pond. To the extent possible given the habitat characteristics present, benthos will be sampled from areas having comparable sediment types and flow regimes. Minimizing habitat variation will allow the identification of population/species composition differences resulting from other factors, such as chemical contamination. A steel rod will be used to probe bottom sediments, and samples will be collected from soft, fine sand and silt areas wherever possible. The benthos

will be surveyed in late spring or early summer and early fall when benthic populations are at or near yearly maxima.

Because the depth of the Pawtuxet River precludes using Surber or Hess samplers, a Ponar or Ekman grab sampler will be used to collect benthic macroinvertebrate samples following methods set forth in ASTM D4342-84 (*Standard Practice for Collecting Benthic Macroinvertebrates with Ponar Grab Sampler*) and ASTM D4343-84 (*Standard Practice for Collecting Benthic Macro-invertebrates with Ekman Grab Sampler*). Samples will be sieved in the field by placing the sample in a bucket, adding screened water and agitating to create a slurry, and then pouring through a U.S. Standard No. 35 sieve. (Field observations in Phase I indicated that the No. 35 sieve is appropriate for Pawtuxet River sediments.) Samples will be preserved in a 10% buffered formalin solution; sample labels will be placed inside and affixed to the outside of the sample containers. The labels will include the sample identification number, name of the water body, sampling location, date, sampling device used, name of sample collector, substrate characteristics, depth, and any other data deemed pertinent. Three replicate samples will be collected at each sampling location.

Data collected from the benthic survey will include enumeration and identification to genus or to the lowest practical taxon. The physical characteristics of the specific sample collection area will be recorded. A sample of substrate from each location will be analyzed for grain size, total organic carbon (TOC) content, and ammonia.

This survey will:

- identify populations at risk under current conditions or potentially at risk under remedial measures;
- investigate the presence or absence of endangered species including the Barrens Bluet Damselfly (*Enallagma recurvatum*)* and the Banded Bog Skimmer Dragonfly (*Williamsonia lintneri*)*;

- evaluate impairment as measured by 1) the presence or absence of indicator species, and 2) differences in community structure (determined by community indices and multivariate analyses);
- determine the applicability of bioassay test organisms by verifying the presence of chironomid larvae in the existing benthic macroinvertebrate community; and
- provide the information needed to determine food webs in the vicinity of the site.

Note: habitat characteristics will be evaluated during the species/population/community structure analyses to ensure that variations due to habitat heterogeneity are not misconstrued as site-related impacts.

(*These species are listed as state endangered species by the Rhode Island Natural Heritage Program. Both species have aquatic larval stages. However, based on their preferred habitat types, it is unlikely that either species will be found in the Pawtuxet River).

Screening-Level Risk Assessment

A screening-level risk assessment will be conducted for the biological receptors associated with the Pawtuxet River, contaminated media, and constituents of potential concern that have been identified. The biological receptors (indicator species) to be used in the screening-level risk assessment will be organisms that are:

- chronically exposed to site-related chemicals; or
- endangered or threatened; or
- of economic importance; or
- exposed to site-related chemicals via food web transfer or other secondary pathways.

Potential exposure of receptors may occur by primary pathways or by secondary pathways involving the transfer of constituents through a food chain or web. Potential exposure pathways will be evaluated for each of the indicator species identified.

Primary pathways to aquatic receptors will be evaluated through direct comparison of surface water and sediment concentrations of constituents of concern with appropriate criteria, standards, or accepted methodologies such as equilibrium partitioning.

For all other pathways the *estimated daily dose* (mg chemical/kg body weight/day) of each constituent of potential concern will be determined for each indicator species based on simple and conservative models employing environmental concentrations of constituents and daily intake through all major pathways. Bioconcentration and food web transfer of contaminants will be considered in the screening level risk assessment models. An *acceptable daily dose* will be estimated by extrapolating from toxicity data in the scientific literature. Extrapolation from data using surrogate chemicals or surrogate species may be necessary if more specific data are not available. The acceptable daily dose will be compared to the estimated daily dose.

The benthic macroinvertebrate community will be assessed as a potential receptor through comparisons of community indices (such as richness, evenness, and diversity as well as the presence/absence of tolerant/sensitive species). Richness is a measure of the number of species within a community. Evenness is a measure of similarity in abundance between species in a community. Diversity is a single statistic into which the number of species and the relative abundance among species are incorporated. It is high for a collection with many species when the abundance is similar among them, and is low when species are few and their abundances different.

The Shannon index of diversity will be applied in this study (Pielou, 1977). The Shannon index is the most widely used index in community ecology, and has been used to evaluate the response of a broad range of aquatic communities to various types of stressors. The expected Shannon Diversity value is usually less than 1 for areas of heavy pollution, between 1 and 3 in areas of moderate pollution, and greater than 3 in clean water areas (Wilhm and Dorris, 1968).

Given that the diversity calculation depends upon independent properties of a community, ambiguity is inevitable. A community with few species that are evenly distributed may have a calculated diversity value similar to a community with many species and uneven abundance. In order to correctly interpret diversity values it is essential to also calculate evenness, for which a number of methods are in use (Ludwig and Reynolds, 1988). Evenness will be calculated by the method of Pielou (1977), which expresses evenness as the ratio of the calculated diversity to the maximum diversity for a community.

(Note: Flow velocity, substrate composition, and stability, grain size, relative abundance of vegetation, and any other pertinent habitat information noted in the field will be considered when evaluating the results of the aquatic surveys. If differences are noticed in these parameters, it may be difficult to relate indices differences to site-related contaminants.)

A report will be generated as a result of the screening-level risk assessment. This report will present:

- the results of the screening level risk assessment including the identification of constituents which may pose a significant risk to the environment;

- data gaps identified during the course of the risk assessment; and

- the need, if one exists, for additional studies. This report will also propose those studies, if necessary.

Species-Specific Fish Survey

An additional fish survey may be needed in order to measure identified endpoints. Such a survey could focus on one or two potential receptor species that would be collected for histopathological examination and/or tissue analysis of contaminant burden. The need for an additional fish survey will be identified in the screening-level risk assessment report.

6.5.4 Conducting Terrestrial Environment Investigations (Task 4)

Based on chemical analyses and bioassays, a potential concern for the Pawtuxet River aquatic community was raised in Phase I. However, any effect on riparian/terrestrial communities with potential exposure to constituents in the Pawutuxet River has not been addressed adequately. The riparian investigations will be based on an initial review of background information. The investigations will include a *site visit* by field biologists and a *screening-level risk assessment.* Any further riparian surveys will be undertaken only if the results of the screening assessment show significant concern.

A determination of "significant concern" will be based on the results of the screening-level risk assessment models. If the hazard quotient for a certain constituent of concern in one of the indicator species is equal to or greater than one based on a comparison of estimated daily intake to acceptable daily intake levels, then it will be concluded that potential risks exist for the specific indicator species.

Site Visit

A site visit will be performed by field biologists in order to characterize the riparian/ terrestrial ecosystems. During this visit, habitat types will be noted and mapped. All wildlife

(or signs thereof) observed also will be recorded. Plant communities will be described and the component species will be identified. Evaluation of the types of vegetation present will provide insight into the bird and mammal species that may be present, as well as information on potential contaminant pathways. The objective of the site visit is to produce a list of species potentially in the area and potentially at risk of exposure to consituents in the Pawtuxet River.

Screening-Level Risk Assessment

A screening-level risk assessment will be conducted for the biological receptors associated with the Pawtuxet River, contaminated media, and constituents of potential concern that have been identified. The biological receptors (indicator species) to be used in the screening-level risk assessment will be organisms that are:

- chronically exposed to site-related chemicals; or
- endangered or threatened; or
- of economic importance; or
- exposed to site-related chemicals via food web transfer or other secondary pathways.

Potential exposure of receptors may occur by primary pathways or by secondary pathways involving the transfer of constituents through a food chain or web. Potential exposure pathways will be evaluated for each of the indicator species identified.

The *estimated daily dose* (mg chemical/kg body weight/day) of each constituent of potential concern will be determined for each indicator species based on simple and conservative models employing environmental concentrations of constituents and daily intake through all major pathways. An *acceptable daily dose* will be estimated by extrapolating from toxicity data in the scientific literature. Extrapolation from data using surrogate chemicals or

surrogate species may be necessary if more specific data are not available. The acceptable daily dose will be compared to the estimated daily dose.

A screening-level risk assessment report for riparian receptors will be generated. This report will:

1) present the results of the assessment based on the literature review, site visit, and screening-level models;

2) identify any data gaps identified during the assessment; and

3) determine the need for additional studies, if necessary.

If the screening-level risk assessment for riparian receptors indicates no signficant increase in risk then this will be documented in the report and no further riparian investigations will be proposed.

Riparian Surveys

The riparian surveys (including a *mammalian survey*, a *herpetile survey*, and a *bird survey*) will be performed only if the results of the screening-level risk assessment indicate significant concern. The objective of the riparian surveys would be to identify significant species of mammals, herpetiles, and birds along the Pawtuxet River that may be impacted by exposure to site-related chemicals. This objective would be met by:

1. determining the presence and estimated numbers of rare, endangered, or sensitive species (either Federal- or State-designated);
2. determining the species and estimated numbers of small mammals, herpetiles, and birds that use the river as feeding habitat;

3. determining the presence of a species of economic or scientific importance; and
4. determining the effects of environmental contaminants on these species, if any.

Mammalian Survey

Mammals in the area of the Pawtuxet River facility would be surveyed by nocturnal observations and habitat searches. Nocturnal observations would be made (either along transects at selected roadside vantage points or from a boat on the river) using a AN/PVS-4 Night Visions System Starlight scope. This scope allows the observer to sight and photograph nocturnal animals without inducing behavioral responses. Habitat searches will be conducted using the belt transect method; mammal signs (including sightings, tracks, burrows, runs, spoor, and carcasses) will be recorded.

These surveys will:

- identify species that may potentially be exposed to site-related chemicals;
- provide information necessary for the ecological assessment; and
- help in determining the food web in the vicinity of the site.

Herpetile Survey

The herpetological fauna in and using the Pawtuxet River will be sampled using four techniques. During the fish survey, any amphibian caught in the nets or electroshocked will be noted and released. In addition, minnow traps will be placed in appropriate breeding areas along the edge of the river to collect aquatic salamanders. Frogs will be monitored 1) by diurnal observation and collection, and 2) during the nocturnal bird survey. River banks and areas containing aquatic vegetation will be spotlighted and data on species identity, abundance, and location will be noted. During the nocturnal survey, all frogs heard calling will be identified by the call. In addition, a series of prerecorded calls of species known to

be in the area will be played on a game caller. Frogs are strongly territorial; they interpret the artificial call as belonging to a rival male and (generally) will respond, which helps to confirm their presence.

Most amphibians constitute the tertiary consumer level in the food chain. Many fish and birds prey on amphibians, so contaminants accumulating in the lower trophic levels might be funnelled up the food chain through amphibians. Many of the organisms that feed on amphibians (e.g., bass and herons) are important economically or recreationally.

Any reptiles (snakes and turtles) sighted during the nocturnal survey also will be noted. In addition, any turtles that are basking will be noted, and turtle traps will be placed near known basking locations (as well as at other appropriate sites along the edge of the river). Traps will be checked daily; any turtles caught will be identified, marked, and released. Because turtles (especially snapping turtles) are noted for their tendency to bioaccumulate contaminants, they typically are an excellent upper-level predator to sample.

In addition to the river-intensive surveys, nocturnal road cruising will be performed on roads near the river. Road cruising allows rapid sampling of large areas for herpetiles moving to and from breeding, nesting, or feeding habitat. Rainy evenings tend to produce the most diverse results using this method because amphibians become more surface-active under these conditions. Overall, the data from the Phase II herpetile survey will:

- identify species endemic to the areas of concern;
- provide information necessary for the ecological assessment evaluation; and
- help in determining the food web in the vicinity of the facility.

Bird Surveys

Avifaunal studies will be conducted in the winter and summer to focus on resident populations using the riverine habitat. Particular attention will be paid to waterfowl and raptors (predators) in the vicinity of the Pawtuxet River and the WWTA pond. The early morning hours are particularly good for sighting birds. In addition, nocturnal observations along the same transects will be made to identify nocturnal birds (e.g., night herons).

A transect survey technique will be used; observation periods will be 15 minutes at each location on a transect. Species observed, time, date, location, habitat, and behavior will be recorded for each location. This survey will:

- identify species endemic to the areas of concern;
- determine presence or absence of endangered species including the American Bittern (*Botaurus lentiginus*)*, the Northern Harrier (*Circus cyaneus*)*, the Roseate Tern (*Sterna dougallii*)*, the Yellow-breasted Chat (*Icteria virens*)* and the Vesper Sparrow (*Pooecetes gramineus*)*;
- evaluate habitat suitability for endangered species that could potentially reside in the area;
- provide information necessary for the ecological assessment evaluation; and
- help in determining the food web in the vicinity of the facility.

*(These species are listed as state endangered species by the Rhode Island Natural Heritage Program (RINHP). Based on information obtained from RINHP, it is unlikely that any of these species would find suitable breeding habitat in the vicinity of the Ciba-Geigy Cranston site).

6.5.5 Performing an Ecological Assessment of the Pawtuxet River (Task 5)

The ecological (risk) assessment of the Pawtuxet River includes an *exposure assessment*, a *toxicity assessment*, and a *risk characterization*.

Exposure Assessment

The exposure assessment will describe how the constituents (in, or transported by, the river) reach the river and WWTA pond ecosystems and define the biological populations at risk. The exposure assessment estimates or measures the amount of each constituent released, tracing it through a pathway to the receptor, and involves two main activities — an *exposure pathway analysis* and *selection of target species*.

Exposure Pathway Analysis

An exposure pathway determines how a constituent can be transported from its source to a receptor in the environment. A potential exposure pathway has five components:

1. a constituent source;
2. a mechanism for contaminant release;
3. an environmental transport medium;
4. an exposure point (receptor location); and
5. a route of exposure.

Integrating the biological investigations with the results from other Phase II studies (and with information available in the scientific literature) will provide the information needed so that the exposure pathway analysis can answer the following questions:

- What receptors are actually or potentially exposed to site-related constituents in the river?
- What are the significant routes of exposure?
- To what concentrations of each constituent are the receptors actually or potentially exposed?
- What is the duration of exposure?

- What is the frequency of exposure?
- What seasonal and climatic variations are likely to affect exposure?
- What are the site-specific geophysical, physical, and chemical conditions affecting exposure?

Selection of Target Species

Target species, target communities, and critical habitats will be selected using five criteria:

- Susceptibility of the species, community, or habitat to site-related constituents associated with the river;
- Relationships between the target species, community, or habitat and the exposure pathways;
- Amount of information in the literature on the target species, community, or habitat;
- Potential for bioaccumulation or biomagnification of the constituents in the target species; and
- Prior success with evaluating toxic effects, based on the scientific literature, for the target species.

Toxicity Assessment

The toxicity assessment weighs the evidence available about the potential for a particular constituent to cause an adverse effect in exposed receptors (target species). It also estimates, where possible, the relationship between the extent of exposure to a constituent and the increased likelihood and/or severity of adverse effects. The toxicity assessment involves three main activities — *hazard identification*, *dose-response assessment*, and *determination of ecological endpoints*.

Hazard Identification

Environmental toxicity information will be obtained for all constituents of concern. If there are constituents without available toxicity information, consideration will be given to an evaluation using toxicity information from compounds exhibiting similar physical/chemical properties and similar biological activities, as is often done in human health risk assessments. Also, much of the evidence available is likely based on laboratory experiments using single species exposed to a single constituent, or on field experiments conducted under conditions that may be much different from those at the facility. The variables that influence toxicity include the nature of the target species, laboratory conditions, the nature of the constituent, concentrations of the constituent, and the duration of exposure. All of these variables will be considered in the hazard identification process, as well as discussed in the uncertainty analysis section.

Dose-Response Assessment

Dose-response assessment is the process of quantitatively evaluating the toxicity data and characterizing the relationship between the dose of the constituent received and the incidence of adverse effects in the exposed population. Toxicity values derived from this quantitative dose-response relationship can be used to estimate the incidence of (or potential for) adverse effects as a function of receptor exposure to a constituent. For this assessment, the estimated applied daily dose will be compared to the acceptable applied daily dose for each constituent of concern to determine whether adverse effects would be expected for each indicator species.

Determination of Ecological Endpoints

An ecological endpoint is an indicator of an adverse effect on the exposed population or community. The "ecological consequences" approach evaluates the possible relationship between the ecological endpoint (e.g., increased mortality or slower growth rate) and one or more of the

site-related constituents. There are four levels of ecological endpoints that are generally considered:

- *Individual* endpoints (for an individual organism) based on increased susceptibility to illness, decreased growth, and death.
- *Population* endpoints (for several individuals of the same species) based on decreased fecundity or sexual maturity, decreased growth rate, increased frequency of disease, and increased mortality rate.
- *Community* endpoints (for several populations in the same location or habitat) based on decreased species diversity, decreased food web diversity, and decreased productivity.
- *Ecosystem* endpoints (for all the physical, chemical, and biological components) based on decreased diversity of the communities.

Very few data exist for evaluations such as this, especially on a site-specific and/or constituent-specific basis. The field investigations proposed for the Phase II environmental assessment are designed to attempt to provide the data needed to evaluate certain community and population endpoints in the Pawtuxet River. Ecological endpoints will be addressed more generally in the context of the screening-level risk assessment models. The lack of sufficient environmental data may preclude the use of anything but individual endpoints.

Risk Characterization

Information from data evaluations, field investigations, and exposure and toxicity assessments will be summarized and integrated into quantitative and qualitative expressions of potential risk to plants and animals from site-related constituents. Media-specific constituent concentrations and known environmental criteria will be compared to characterize potential biological effects. The risk characterization involves two main activities — a *risk analysis* and an *uncertainty analysis*.

Risk Analysis

The potential risk posed by identified constituents related to releases from the facility will be assessed by:

- comparing exposure point concentrations to published criteria or doses with known adverse effects;
- comparing on-site ecological populations of plants or animals existing in affected areas to unaffected or "reference" areas; or
- comparing estimated daily intakes to acceptable daily intakes for each constituent of concern for the exposed indicator species.

Note: For the present investigation, reference area comparisons will be made only for the benthic macroinvertebrate survey and the fish survey. The reference stations will be located upstream from the site to eliminate the possibility of contamination from site-related constituents. In addition, the reference stations will be located in stream areas with similar physical characteristics (flow velocity, depth, substrate cover, etc.) to the stations sampled within the zone of potential contamination.

Uncertainty Analysis

All risk estimates depend on numerous assumptions and contain many uncertainties that are inherent in the evaluation process. Toxicity information used in evaluating the constituents of concern contain one source of uncertainty. There is often adequate evidence that the constituent will cause an increase in the incidence of an adverse effect, but direct evidence that the adverse effect is likely to occur in a particular animal or plant species may be limited. In addition, much of the toxicological evidence is based on laboratory experiments using single species exposed to single constituents. Actual field exposures may be quite different. Variables that influence toxicity and, thus, contribute to uncertainty are; the nature of the target species, laboratory

conditions, the nature of the constituent, concentration of the constituent, and the duration of exposure. In any evaluation of the level of risk associated with a site, it is necessary to address the level of confidence. (ie. or the uncertainty associated with the estimated risk).

Two major areas of uncertainty exist in the screening-level risk assessment models. The first is in the estimation of daily intakes of each constituent of concern for each indicator species. The second is in the derivation of the acceptable daily intakes for each constituent of concern for each indicator species.

Daily intakes are calculated by estimating daily intakes of food, water, and air for each indicator species. These daily intakes are either literature values or estimations based on body size and metabolic rates. Allometric equations are used to describe the relationship between body weight and food or water consumption rate. Such allometric equations are available between different fish classes, birds and mammals. These estimations introduce uncertainty into this assessment.

Acceptable daily intakes for each indicator species are based on maximum dosages that are not expected to have long term adverse effects on the animal. Since these values may not exist for each indicator species and each constituent of concern, values from similar species may have to be used. Also, many of these values are derived from laboratory tests using only one chemical. Uncertainty is introduced into this assessment since the animals on-site will be exposed to a combination of chemicals under different environmental conditions than those in the laboratory.

6.6 CONSIDERATIONS FOR THE PHASE II ENVIRONMENTAL ASSESSMENT

Other considerations for the Phase II environmental assessment of the Pawtuxet River — including integration of the environmental data with other Phase II studies, as well as contingencies for the Phase II environmental assessment — are discussed here.

Integration with Other Phase II Studies

As discussed earlier, the results from the hydrological investigation and Pawtuxet River release characterization will be integrated and used to support the Phase II environmental assessment.

Contingencies for the Phase II Environmental Assessment

The field investigations are designed to be conducted in appropriate seasons; completion of these investigations on schedule is contingent on 1) beginning all tasks on schedule, and 2) obtaining appropriate collection permits on schedule. The decision to conduct species-specific fish or riparian surveys are contingent on the result of the screening level assessment and the risk assessment report and may be contingent on completion of the 1) release characterization of sediment, and 2) hydrological modeling.

6.7 SUMMARY

The Phase II environmental assessment will assess the risk to the Pawtuxet River environment with regard to site-related contaminants. The strategy for the Phase II environmental assessment involves:

- conducting toxicity identification evaluations;
- conducting a literature review;
- conducting surveys of benthos, fish, mammals, herpetiles, and birds in and around the Pawtuxet River; and
- integrating the findings to characterize potential biological effects.

The next chapter discusses project management issues for the Phase II river investigations.

- An ecological characterization of the upstream reach, including basic water quality data and an inventory of biota, is needed to establish baseline conditions.

- Characterization of the biota is needed to determine whether the ecotoxicological effects identified in Phase I have had an impact on the community.

- The vicinity of the site contains a variety of suitable habitats (e.g., woodlands, wetlands, and the river) for resident and migratory mammals, birds, and waterfowl; the identity of possible receptors of site-related constituents needs to be determined.

- The presence or absence of State- or Federally-designated threatened or endangered species or other sensitive natural resources needs to be ascertained.

- The exposure scenarios of the potential receptors to the constituents need to be identified.

- The risk of effects due to exposure needs to be characterized.

- The contribution of constituents to observed toxicity needs to be identified in order to discriminate site-related effects.

The Phase II environmental assessment will assess the risk to the Pawtuxet River environment with regard to site-related contaminants. The strategy for the Phase II environmental assessment involves:

- conducting toxicity identification evaluations;
- conducting a literature review;
- conducting surveys of benthos, fish, mammals, herpetiles, and birds in and around the Pawtuxet River; and
- integrating the findings to characterize potential biological effects.

References

American Society for Testing and Materials, 1973, Cairns, J. Jr. and K.L. Dickson (eds.), Biological Methods for the Assessment of Water Quality, ASTM Sp. Tech. Pub. 528, American Society for Testing and Materials, Philadelphia, Pennsylvania.

Guy, H.P., 1969, Laboratory Theory and Methods for Sediment Analysis, Book 5, US Geological Survey, pp. 55.

Hendricks, M.L., C.H. Hocutt, and J.r. Stauffer, Jr., 1980, "Monitoring Fish in Lotic Habitats," in Biological Monitoring of Fish. (C.H. Hocutt and J.R. Stauffer, Jr., Eds.) D.C. Heath Co., Lexington, Massachusetts.

Hilsenhoff, W.L., 1988, "Rapid Field Assessment of Organic Pollution with a Family Level Biotic Index," J.N. Am. Benthol. Soc., Vol. 7(1): 65-68.

Ludwig, J.A., and J.F. Reynolds, 1988, Statistical Ecology, John Wiley & Sons, New York, NY.

Pielou, E.C., 1977, Mathematical Ecology, John Wiley & Sons, New York, NY.

Welch, P.S., 1948. Limnological Methods, McGraw-Hill Book Co., New York, New York.

Wetzel, R.G., 1983, Limnology, W.B. Saunders Company, Philadelphia, PA.

Wilhm, J.L. and T.C. Dorris, 1968, "Biological Parameters for Water Quality Criteria," BioScience, Vol. 18, No. 6, pp. 477-480.

Zar, J.H., 1974, Biostatistical Analysis, Prentice Hall, Inc., Englewood Cliffs, NJ.

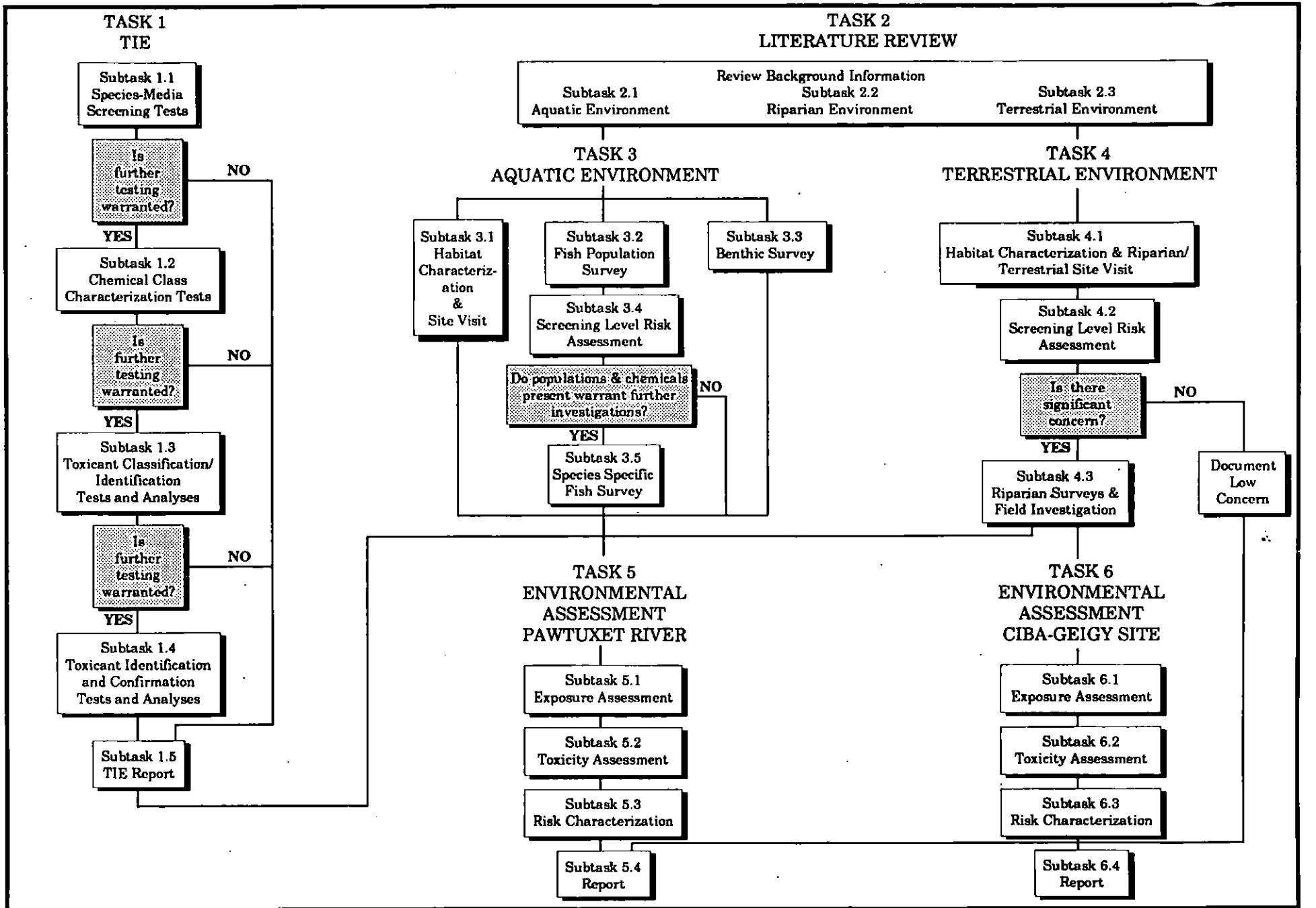


FIGURE 6–2 OVERVIEW OF RFI RISK ASSESSMENT

C

Round 1 Sediment Sampling

A Ponar grab sampler was used to collect sediment samples. Multiple grabs (a minimum of two) were needed to obtain sufficient sediment and pore water. The sediment samples were placed in 7-gallon polyethylene bags within 5-gallon polypropylene buckets. The bags were sealed and packed in ice for transport to the bioassay laboratory. All samples were stored at the laboratory in refrigerators maintained at about 4°C.

The sediment samples were removed from cold storage on 12 December 1990, and all waters over the surface of the sediments were decanted. The sediments were then stirred with a polyvinyl chloride (PVC) rod and aliquots of roughly 40 ml were removed. These were placed in disposable 50-ml polypropylene centrifuge tubes and centrifuged at 20,000 rpm for 20 minutes in a Sorvall Superspeed Model RC2-B refrigerated centrifuge with a Sorvall Instruments SS-34 rotor. The extracted interstitial waters were decanted into 500-ml polypropylene bottles. This process was repeated until at least 400 ml of pore water was obtained from each of the 10 sediment samples. Each pore water sample was then vacuum-filtered through a 0.45-µm glass microfiber filter to remove suspended solids that could confound the bioassay by interfering with *C. dubia* movement. Pore water samples were stored at about 4°C until testing began.

The physical handling procedures (i.e., stirring, centrifuging, and vacuum-filtering) may result in changes in constituent concentrations or bioavailability of constituents. In particular, volatile compounds can easily be lost during homogenization by stirring or during vacuum filtration. This can lead to a decrease in toxicity. Conversely, the loss of volatile sulfides may cause some inorganic constituents to become more bioavailable, thus increasing toxicity. In any event, the laboratory toxicity tests may not accurately reflect field conditions and may either over- or under-estimate toxicity.

The remaining sediments were then filtered through an American Society for Testing and Materials (ASTM) Standard No. 18 sieve with 1-mm openings to remove large particles and endemic animals, especially predators. Sieving the sediments was performed without introducting additional water. The sieved sediment samples were stored in the dark at about 4°C until testing began. Table D-4 (in Appendix D) summarizes the physical descriptions of the Round 1 sediment samples. The samples ranged in consistency from coarse sand to silt.

C.2.2 Round 2 Sampling

Results from the Round 1 bioassay tests (discussed in Chapter 3) indicated that surface water was not toxic either to the fathead minnow or the water flea. However, four of the six sediment samples from the facility reach were toxic to midge larvae that had direct contact with the sediment. In addition, pore water from two of these six samples was toxic to *ceriodaphnia dubia*. Thus, the Round 2 bioassay tests were limited to testing the toxicity of sediments on midge larvae.

Round 2 Sampling Strategy

In general, the Round 2 sampling locations were selected for their proximity to facility outfalls and past releases, to confirm the results from Round 1, or to delineate further the areas of toxicity suggested by the results from Round 1. Upstream and downstream of the facility, sampling locations were selected at meander bends or at other areas likely to afford sediments. Within the facility reach, sampling locations were selected either where high concentrations of compounds were expected (because of facility activities or river dynamics) or at points that would help to delineate the extent of contamination.

Round 2 Sampling Locations

Figures 3-5, 3-7, 3-9, and 3-11 (in Chapter 3) show the fourteen sediment sampling locations selected for bioassay testing in Round 2. The sampling locations ranged from about 0.3 miles upstream to about 0.7 miles downstream of the facility. SD-00L and SD-01R were upstream of the facility. Eight locations — SD-02R, SD-02L, SD-03R, SD-03L, SD-04R, SD-05M, SD-07L, and SD-08M — were in the facility reach. SD-09R, SD-13R, SD-16L, and SD-20M were downstream of the facility.

D

FLOW CONDITIONS AND PHYSICOCHEMICAL DATA

D.1 OVERVIEW

This appendix describes the flow conditions of the Pawtuxet River during the Phase I release characterization sampling activities, and also presents the physicochemical/water quality results from analyses of Phase I release characterization samples. (Geotechnical data for the samples collected from the river during the Phase I hydrological investigation were discussed in Appendix F of the Phase I Interim Report.)

D.2 FLOW CONDITIONS IN THE PHASE I RELEASE CHARACTERIZATION

This section discusses and compares the flow conditions of the river during both sampling rounds of the release characterization. Round 1 sampling was performed from 27 to 30 November 1990, on 3 December 1990, and on 7 December 1990. Round 2 sampling was performed from 26 to 29 March 1991 and from 1 to 3 April 1991. Table D-1 lists the weather conditions and media sampled on each date.

Flow conditions can be evaluated by estimating discharge from a rating curve — measurements of the river stage are applied to the facility-specific rating curves to estimate discharge. The facility-specific rating curves were developed from the instantaneous discharge measurements and stage measurements made at the upstream and downstream ends of the facility reach during the Phase I hydrological investigation. Round 1 stage measurements correspond to an estimated discharge of 150 to 190 cubic feet per second (cfs). (The range of estimated discharge results from using two slightly different rating curves.) However, note that the facility-specific rating curves are based on few data. Because all the Round 2 stage values were larger than the range in the facility-specific rating curves, the curves cannot properly be used to estimate discharge during Round 2 sampling.

Instantaneous or average daily discharge values (measured from 1934 to present) at the USGS-WRD gauge at Cranston (hereafter, simply the "Cranston gauge") also are shown in Table D-1. The values for the Cranston gauge are considerably higher than the Round 1 estimated discharge values at the facility (about 265 cfs compared to about 170 cfs), possibly because of 1) the time lag between the Cranston gauge and the facility, and 2) the areal variation in rainfall and runoff. The high springtime flows measured during Round 2 sampling cannot be accounted for using the facility-specific rating curves.

Total suspended sediment (TSS) concentrations for surface water can be combined with discharge values to estimate suspended sediment discharge based on the assumption (not necessarily valid) that the maximum TSS concentration measured in the samples applies throughout a theoretical river cross-section. During Round 1, the maximum TSS concentration was 9 mg/l. TSS was not detected in any of the Round 2 samples and the method detection limit was 10 mg/l, so a TSS concentration of 9 mg/l was assumed for both Rounds 1 and 2. Using 170 and 1040 cfs as the discharges for Rounds 1 and 2 (respectively), the suspended sediment discharge estimates are 4668 and 28,559 kg/day (respectively).

The Round 1 estimated discharges and instantaneous discharges are within the range of discharge measured during the hydrological investigation. As discussed in Chapter 2, the range of streamflows measured during the hydrological investigation roughly represented median conditions

detected to 5 meq/100g and TOC ranges from 370 to 4900 ppm. The changes in CEC and TOC from Round 1 to Round 2 at confirmation sample locations (SD-02R, SD-02L, SD-03R, SD-03L, SD-07L, and SD-08M) show no consistent relation to changes in grain size. For the push-cored samples, porosity ranged from 51.3 to 83.7 and bulk density ranged from 74.5 to 107.9 pounds per cubic foot (pcf).

The levels of sulfide and ammonia show a rough correspondence with grain size. In the finer-grained push-cored samples, sulfide ranged from not detected to 17,000 ppm and ammonia ranged from not detected to 140 ppm. For the coarser-grained grab samples, sulfide ranged from not detected to 49 ppm and ammonia ranged from 5 to 33 ppm. In addition, collection of grab samples (for the coarse-grained material) provides greater opportunity for volatilization of these compounds than collection of push core samples (for fine-grained material). The two sets of sediment samples (i.e., push cores versus grabs) overlap considerably with respect to nitrite-nitrate and orthophosphate; however, nitrate-nitrite and orthophosphate values were higher in the Round 2 samples.

D.5 PHYSICOCHEMICAL DATA FROM THE DOWNSTREAM REACH

This section discusses the results from physicochemical analyses of sediment samples from the downstream reach during the Pawtuxet River release characterization; the results for surface water samples were discussed in Section D.3 ("PHYSICOCHEMICAL DATA FROM THE UPSTREAM REACH").

All seven samples were collected as grabs. Samples SD-09R and SD-13R were fine sand; all other samples were medium to coarse sands. The values for CEC and TOC are comparable to the range measured in the upstream and facility reaches: not detected to 12 meq/100g for CEC and 310 to 11,000 ppm for TOC. The higher values of CEC and TOC were in samples SD-09R and SD-13R; this result is expected because these samples have a finer grain size.

The levels of sulfide, ammonia, and nutrients in the downstream sediment samples show a rough correspondence to the grain size of the samples. In the finer-grained samples (SD-09R and SD-13R), sulfide was not detected, ammonia ranged from 43 to 47 ppm, nitrite-nitrate ranged from not detected to 2 ppm, and orthophosphate ranged from 27 to 34 ppm. In the coarser-grained samples (SD-09AL, SD-10M, SD-16L, and SD-20M), sulfide generally was higher (not detected to 120 ppm), ammonia generally lower (7.4 to 22 ppm), nitrite-nitrate generally higher (not detected to 53 ppm), and orthophosphate generally lower (0.5 to 30 ppm). The major difference between the Round 1 and Round 2 data is that nitrite-nitrate values were much higher in all the Round 2 samples.

D.6 SUMMARY

The flow conditions and physicochemical data for surface water and sediment samples from the Phase I Pawtuxet River release characterization are summarized here.

Flow Conditions

The discharge values for the Cranston gauge are considerably higher than the estimated discharge values at the facility (about 265 cfs compared to about 170 cfs), possibly because of 1) the time lag between the Cranston gauge and the facility, and 2) the areal variation in rainfall and runoff. However, the facility-specific rating curves may be inadequate for estimating discharge. A TSS concentration of 9 mg/l was assumed for both Rounds 1 and 2. Using 170 and 1040 cfs as the discharges for Rounds 1 and 2 (respectively), the suspended sediment discharge estimates are 4668 and 28,559 kg/day (respectively). The Round 1 estimated discharges and instantaneous discharges are within the range of discharge measured during the hydrological investigation (which roughly represented median conditions on the river, based on records from the Cranston gauge). Flow conditions were moderate during Round 1 sampling, but were approaching a flood stage during Round 2 sampling. Round 1 estimated suspended sediment discharge is comparable to that

measured during the hydrological investigation, but Round 2 estimated suspended sediment discharge is much higher.

APPENDIX E
PHASE II MODELING OF THE PAWTUXET RIVER

E.1 OVERVIEW

This appendix proposes a work plan for the Phase II modeling of the Pawtuxet River (or simply, the "Phase II river modeling") that includes a predictive mass balance water quality and sediment model capable of simulating the transport and fate of contaminants in the river. The overall objective of this work plan is to develop interrelated models which will permit evaluation of the temporal and spatial concentration reductions resulting from remedial action alternatives considered for the facility and the river.

The Phase II Pawtuxet River modeling work plan will develop three interrelated models:

- a *hydrodynamic* model;
- a *sediment transport* model; and
- a *chemical fate* model (sometimes called a "contaminant fate model").

Taken together, these three modeling efforts will be referred to as the Phase II "contaminant transport and fate modeling". Developing each of these models involves 1) initialization using field data, and 2) subsequent calibration by comparing calculated values and field data. The projected (i.e., predicted) concentrations that result from this Phase II modeling will permit characterization of the reduction in risk to environmental receptors that results from any remediation.

In general, the following activities will be conducted in the Phase II river modeling:

- Existing Pawtuxet River water column and sediment contaminant concentration data will be used to establish a contaminant ranking based on relevant ecological or human health risk endpoints.
- Field studies will be performed to obtain data for developing and calibrating a contaminant transport and fate model.
- Extreme flow-induced erosion and downstream migration of contaminants currently in river sediments in the cofferdam area will be projected.
- Mechanisms controlling the fate of individual contaminants within the river will be determined.
- A model of sediment and contaminant transport and fate in the river will be developed and calibrated.
- Temporal and spatial changes in sediment and water column contaminant concentrations resulting from potential remedial actions conducted at the facility and in the river will be estimated.

E.2 PHASE I DATA GAPS / PHASE II DATA NEEDS

Both physical and chemical data are required for the Phase II river models. The work plan for collecting the physical data needed was discussed in Chapter 4; the work plan for collecting the chemical data needed is discussed in this appendix. In general, the Phase II river modeling effort is designed to fill data gaps remaining from both the Phase I hydrological investigation (discussed in Chapter 2) and the Phase I Pawtuxet River release characterization (discussed in Chapter 3).

The two data gaps remaining from the Phase I hydrological investigation are:

- Additional discharge information is needed.
- The river system hydrology is not defined adequately.

The data gap remaining from the Phase I Pawtuxet River release characterization is that more complete evaluation of the factors influencing contaminant movement in the river is needed.

In addition, several specific data needs were identified for Phase II:

- Additional bathymetry data is needed to define the river geometry accurately throughout the study area.
- Stage heights need to be measured in the facility reach and at the Pawtuxet Cove Dam to develop stage-discharge relationships.
- Physical characteristics of the riverbed sediments need to be determined to support sediment transport modeling.
- The resuspension characteristics of the riverbed sediments need to be evaluated.
- Routine water column solids monitoring needs to be conducted to provide data for calibrating the sediment transport model.
- Water column contaminant and solids sampling and analyses need to be conducted during two high flow events to provide data for calibrating both the sediment transport and chemical fate models.
- Riverbed sediment samples need to be analyzed for contaminant concentrations to support chemical fate modeling.
- Routine water column contaminant monitoring needs to be conducted to provide data for calibrating the chemical fate model.

The objective of Phase II river modeling is to fill these Phase I data gaps and Phase II data needs.

E.3 STRATEGY FOR THE PHASE II PAWTUXET RIVER MODELING

In order to meet this objective, the strategy for the Phase II river modeling effort is to address the data gaps/data needs by:

- conducting a high flow survey of the river;
- conducting riverbed sediment sampling;
- conducting routine water column monitoring in the river; and
- developing a contaminant transport and fate model of the river.

The strategies for these activities are discussed here; methods and analyses for implementing these activities are discussed in Section E.4 ("Methods and Analyses for the Phase II Pawtuxet River Modeling").

E.3.1 High Flow Survey

A key test in developing a credible sediment transport/chemical fate model is demonstrating that the model can simulate flood events accurately. This test requires collecting suspended solids and contaminant concentration data during at least two high flow events (i.e., a flow rate greater than 1000 cfs). Data collected during these events will be used to calibrate and verify the models.

Suspended sediment concentrations increase and decrease relatively quickly during a flood; daily measurements will not produce adequate temporal resolution during a flood. Suspended solids measurements need to be taken about once every four hours during a flood. Because of the unpredictable nature of floods, automated suspended solids samplers are the best method for ensuring that the data will be collected reliably during a flood.

E.3.2 Sediment Sampling

The resuspension potential of cohesive sediments is somewhat site-specific in that it depends on physical characteristics of the particles (such as grain size, density, and organic coating). Empirical determination of the relationship between surface shear stress and resuspension is needed to define the site-specific constant of the resuspension equation used in the sediment transport model.

A critical component of the contaminant transport and fate model is the description of the existing three-dimensional sediment bed concentration profiles of the contaminants. Sediment cores will be collected to define concentration profiles of the contaminants throughout the river. Sediment sampling locations will be selected after sediment characteristics have been mapped (as discussed in Chapter 4). The data will serve as input for the contaminant transport and fate modeling.

E.3.3 Routine Water Column Monitoring

Routine monitoring is proposed to provide data that will:

- define the spatial profiles of the contaminants being modeled;
- allow assessment of the relationships between contaminant concentration and river flow; and
- describe the partitioning of contaminants between dissolved and particulate phases.

Filtered and unfiltered water column samples will be collected once per week at six stations for a time period covering both the (high flow) spring season and the (low flow) summer season. The filtered samples will be analyzed for organic carbon and the contaminants being modeled; the unfiltered samples will be analyzed for total suspended solids, particulate organic carbon, pH, temperature, and the contaminants being modeled. The sampling stations will be positioned to allow determination of:

- contaminant concentrations entering the study area;
- concentration changes due to point source and tributary inputs upstream of the facility; and
- concentration changes through the facility reach and downstream of the facility to the Pawtuxet Cove Dam.

The data will serve as input for the contaminant transport and fate modeling.

E.3.4 Contaminant Transport and Fate Modeling

Developing a contaminant transport and fate model involves:

- describing the physical system;
- quantifying the hydrologic, solids, and contaminant inputs to the system; and
- parameterizing the transport, phase transfer, and reaction processes affecting the contaminants.

Ranges of process parameter values are established from published laboratory and field data. Specific values will be defined by comparison of computed and observed Pawtuxet River contaminant concentrations (i.e., during model calibration).

A subset (about 5) of the target compounds established in Phase I will be modeled and will include the compounds that contribute most significantly to the public health or environmental risk posed by contamination of the river. Ideally, the compounds in the subset would span a range of characteristics sufficient to provide calibrated models valid for use with all other potential target compounds. The first step will be to determine the compounds to be modeled.

In general, developing the model involves data analysis and model calibration; the specific activities involved in developing the model include:

- compiling and analyzing geomorphological and hydrological data about the river;
- quantifying the solids and contaminant loadings to the river;
- compiling and evaluating river solids and contaminant concentration data;
- analyzing the data collected in the field resuspension investigations;
- developing and calibrating the hydrodynamic model;
- developing and calibrating the sediment transport model;
- performing sensitivity analyses with the chemical fate model; and
- developing and calibrating the chemical fate model for each of the chemicals modeled.

After the three individual models have been calibrated, they will be integrated and used to project changes in the concentrations of constituents in the water column and sediment resulting from remedial action alternatives evaluated for the facility or the river.

E.4 METHODS AND ANALYSES FOR THE PHASE II PAWTUXET RIVER MODELING

This section describes the detailed methods and analyses proposed for:

- analyzing existing data;
- conducting the high flow survey;
- conducting sediment sampling;
- conducting routine water column monitoring;
- analyzing the data to support river modeling;
- developing and calibrating the hydrodynamic model;
- developing and calibrating the sediment transport model;
- developing and calibrating the chemical fate model; and
- projecting future contaminant concentrations.

E.4.1 Analyzing Existing Data

Analyzing existing data will involve evaluating existing *contaminant*, *sediment characteristics*, *river flow*, and *river geometry* data.

Evaluating Existing Contaminant Data

The evaluation of existing contaminant data will involve:

- compiling the data available;
- evaluating spatial and temporal trends in the data;
- assessing the significance of contaminant concentration levels;
- compiling fate characteristics of the contaminants to be modeled; and
- estimating contaminant input to the river from groundwater discharge.

Compiling the Data Available

Historical contaminant data for the water column and sediment bed will be added to the data collected in Phase I. Contaminant monitoring conducted during Phase I provides data for recent time periods. Sources of historical data have been identified (Quinn, 1985; Rhode Island Statewide Planning Program, 1977; USGS, 1990). Additional contaminant data that may be included in the USEPA STORET data base will be retrieved and other data sources that may be identified also will be reviewed.

Evaluating Spatial and Temporal Trends

The existing contaminant data that is compiled will be used to evaluate spatial and temporal trends in water column and sediment bed concentrations. These trends may provide insight into the location of possible sources of contaminant inputs to the river, as well as changes in the magnitude of inputs over time. In addition, temporal trends in contaminant concentrations can provide an indication of the possible future conditions when interpreted in conjunction with other important factors (such as temporal patterns in river flow and land use).

Determining the Chemicals to be Modeled

Contaminant concentrations measured in Pawtuxet River surface water and sediments during Phase I will be used to establish a contaminant ranking based on relevant ecological or human health risk endpoints. Appropriate criteria for ranking include National Water Quality Criteria, Rhode Island Water Quality Standards, and proposed National Sediment Quality Criteria. In addition, if human health risk exists through consumption of fish or fish-eating animals, USEPA Carcinogen Ranking and Oral Reference Doses also will be relevant criteria. Contaminant concentrations will be normalized by the criteria values and then ranked. For comparison to Oral Reference Doses, proposed USEPA guidelines will be used to convert the contaminant concentrations to tissue concentrations in consumable animals.

Once a risk-based ranking of the contaminants is established, those chemicals ranked highest will be modeled. In choosing contaminants for modeling, we will attempt to encompass a broad range of environmental fate characteristics so that the calibrated models can be used to estimate the fate of other chemicals potentially contributing to risk, if needed. The number of chemicals for which calibrations will be conducted will depend on the results of the ranking, but is expected to be about five.

Compiling Fate Characteristics

As a first step in preparing to analyze the contaminants to be modeled, relevant fate charac- teristics will be compiled. The major fate processes include volatilization, diffusion (both within pore water and between the water column and sediment), adsorption-desorption, and both biotic and abiotic decay. The importance of each of these processes will depend on the contaminants being studied.

Estimating Contaminant Input to the River from Groundwater Discharge

The mathematical model will require evaluation of the inputs of contaminants to the river. A preliminary estimate of the contribution of contaminants from groundwater discharges will be based on the existing Phase I contaminant monitoring data and hydrogeological studies. The product of measured contaminant concentrations and the estimated groundwater flow rate will provide the mass input rate required by the model. Additional information obtained during Phase II will be used to refine these preliminary estimates.

Existing Sediment Characteristics Data

Existing data about sediment characteristics fall into two categories — *suspended sediment concentration data* and *sediment bed composition data*. In general, these data will be compiled from USGS records and from the results of the Phase I investigations.

Suspended Sediment Concentration Data

Suspended sediment concentration measurements have been collected at Cranston (upstream of the facility reach) and Pawtuxet (downstream of the facility reach) from November 1978 through June 1991. These historical data will be combined with measurements made in the facility reach during Phase I. The resulting data base will then be analyzed to determine the relationship between suspended solids and flow rate in the Pawtuxet River, both upstream and downstream of the facility reach.

Sediment Bed Composition Data

Compositional characteristics of the sediment bed in the facility reach were examined in Phase I. Sediment grain size, bed porosity, and total organic carbon (TOC) were measured at various locations in the facility reach. The spatial distribution of these data will be analyzed to generate a preliminary sediment bed map of the Pawtuxet River in the study area.

Existing River Flow Data

The USGS maintains a stage height gauge at Cranston; data have been collected at the gauge since December 1939. These historical data will be analyzed to determine a flood flow frequency curve for the Pawtuxet River. This analysis will provide flow rates for extreme events (e.g., 10-, 50-, and 100-year floods). Standard USGS methods for calculating a flood frequency curve will be used (USGS, 1982).

Existing River Geometry Data

A key element in developing a realistic hydrodynamic/sediment transport model is accurate bathymetry/geometry data. The primary source of bathymetric data is likely to be the Phase I study; U.S. Army Corps of Engineers depth soundings and NOAA navigation charts do not exist for the Pawtuxet River. Thus, bathymetry data are currently limited to the 2200-foot reach in the vicinity of the facility. Water depths in the rest of the 4.5-mile reach of the Pawtuxet River from Cranston to the Pawtuxet Cove Dam probably have not been measured. River bank location (which determines channel width) also was determined during the Phase I study, but only in the facility reach. The channel geometry in the upstream and downstream reaches will be determined from a USGS topographic map (1:24,000 scale) of the Pawtuxet River area. These estimates will be revised after Phase II bathymetric data become available.

The importance of sediment erosion during a flood requires that river hydrodynamics be modeled correctly during these extreme events. Data on flood plain width will be analyzed to determine if flood plain effects are hydrodynamically significant during the 100-year flood. The Federal Emergency Management Agency (FEMA) would be the primary source of any existing flood plain data for the Pawtuxet River.

E.4.2 Methods and Analyses for the High Flow Survey

Conducting the high flow survey involves *establishing monitoring stations* and *collecting samples*.

Establishing Monitoring Stations

In Phase II, six monitoring (sampling) stations will be established for both the high flow survey and routine water quality monitoring at the locations shown in Figure E-1:

- Station 1 — the USGS Cranston flow gauge;
- Station 2 — downstream of the Pocasset River;
- Station 3 — at the upstream end of the facility reach;
- Station 4 — midway through the facility reach;
- Station 5 — at the downstream end of the facility reach; and
- Station 6 — upstream of the Pawtuxet Cove Dam.

Stations 1, 4, and 6 will be used for the high flow survey; all six stations will be used for routine water quality monitoring (discussed later in this section). At the high flow survey stations (1, 4, and 6), a small concrete block or metal building will be constructed to house the sampling equipment (e.g., ISCO water sampler and data logger). The other three stations (2, 3, and 5) will be identified by installing a permanent surveyed marker to provide a reference location for all sampling events.

An ISCO continuous sequential automatic water sampler will be installed within the housing unit at Stations 1, 4, and 6. The intake line will run from the housing unit into the river, at least 25 feet from shore, and will be anchored at least one foot above the sediment bed. Before installation begins, the distance between the water and water sampler will be measured to determine if an additional pump is needed. The automated samplers (at all three locations) should be installed before the spring runoff, probably in late February to early March (depending on ice conditions).

Water will be pumped continuously from the river to the building and back to the river inside buried pipe (to prevent freezing and vandalism). An external power source will be required to operate the sampler (and an additional pump, if necessary). The water sampler will be programmed according to the manufacturer's operation manual to obtain the required sample. Screens will be placed on the suction line to prevent floating debris from being drawn into the line; the screens will be cleaned and/or repaired regularly. Sample containers within the water sampler will be removed and replaced with empty containers when sampling capacity is reached. Ice will be placed inside the water sampler to maintain samples below ambient temperature.

Collecting Samples

A 1-liter sample will be taken every four hours at each station. The automated samplers will be serviced once every three days, and all water samples will be analyzed within three days of servicing. The samplers will be operated continuously until late May. Only samples collected during a high-flow event will need to be analyzed individually (i.e., on a four-hour sample basis). These unfiltered samples will be analyzed for pH, the chemicals being modeled, total suspended solids, and particulate organic carbon. All other samples (collected during low to medium flow conditions) can be composited on a daily basis. The composites will be created by thoroughly mixing all six 1-liter samples collected during a 24-hour period, and then withdrawing a 1-liter sample from the 6-liter mixture. These daily composite samples will be analyzed only for total suspended solids.

E.4.3 Methods and Analyses for Sediment Sampling

The sediments of the Pawtuxet river in the vicinity of the CIBA-GEIGY facility are characterized by significant variability in physical characteristics and contaminant concentrations. In order to calibrate and apply the water quality model being developed for this site it is necessary to quantitatively characterize the spatial distribution of contaminant concentrations. Such quantification requires a sampling density greater than that employed in Phase 1 and detection limits lower than those attained in Phase 1.

In order to avoid collecting sediment samples immediately following a significant resuspension event, sampling will not be conducted within three days of a rain event which causes river flow to increase to 700 cfs or greater (at the USGS Cranston gage). Sediment transport modeling of the Pawtuxet River indicates that at flow less than 700 cfs resuspension is negligible and starts to become significant at flows greater than 1000 cfs.

Contaminant Sampling

In addition to quantifying the longitudinal and lateral concentration gradients, the vertical concentration profile must be defined. Because of the temporal variability in contaminant loading to the river, the contaminant concentrations in the sediment will vary with depth. Surficial sediments (top 2 to 10 cm) actively interact with the water column and are the habitat of epibenthic and infaunal organisms. Contaminants associated with these sediments have a direct impact on water column contaminant concentrations and sediment toxicity. Contaminants associated with deeper sediments have a more limited impact that occurs by way of diffusion through the interstitial water to the surficial layer. However, they may be scoured up during extreme flow events.

The model will operationally divide the sediment bed into two categories: cohesive and non-cohesive. Cohesive sediments are defined as those sediments having a median particle diameter less than 250 μm and containing greater than 15 percent silt and clay sized particles. These sediments also tend to have high total organic carbon (TOC) concentrations. Sediments defined as non-cohesive include areas having low and high TOC concentrations. Since the organic carbon content of the sediment is a determinant of the ability of the sediment to sorb organic contaminants, the non-cohesive sediments have been sub-divided into high and low TOC areas using a TOC of 1 percent as the dividing line. Average contaminant concentrations for each of the sediment types are necessary for the model.

Thus, the sediment sampling program has two goals. The first of these is to quantitatively define the longitudinal, lateral and vertical contaminant concentration gradients that exist within the study area. The second is to determine the differences in concentration between sediments characterized as cohesive, high TOC non-cohesive and low TOC non-cohesive.

Sampling Approach

The sediment bed within the study area has been divided into a 360 element grid for sampling purposes. This grid includes 6 lateral divisions and 60 longitudinal divisions with longitudinally varying resolution in order to resolve the expected gradients. Based on Phase I data the most pronounced gradients were observed in the facility reach and it is in this section of the grid where the finest resolution is specified. Using data from the recently completed sediment characterization study, each of these elements has been designated as containing cohesive or non-cohesive sediments. From a modeling perspective, the ideal sampling program would be directed to defining an average contaminant concentration for each grid element. Such a program is not logistically or financially feasible, nor is it technically necessary. By sampling within a subset of the grid elements, concentrations in unsampled elements may be interpolated based on concentration gradients and relevant physical characteristics such as sediment type and TOC content.

The Phase I data indicate that the greatest spatial variability in sediment contaminant concentrations exists adjacent to the CIBA-GEIGY facility. As illustrated for toluene, chlorobenzene and naphthalene in Figure E-2, concentrations in this area of the river range over four to five orders of magnitude, with highest concentrations in the area of the former coffer dam. Much of this variability appears to be related to both sediment type and proximity to the coffer dam. The limited data in the reaches above and below the facility show much lower concentration gradients. Consequently, quantitative characterization of the spatial concentration gradients requires that the majority of the sampling effort be confined to the facility reach.

A total of 51 grid elements or sampling areas have been chosen. Reflecting the spatial concentration gradients, 27 of these areas are within the 0.4 mile facility reach, 9 are in the 3 mile upstream reach and 15 are in the 1 mile downstream reach. The sampling densities for the facility, upstream and downstream reaches are 68, 3 and 15 areas per mile, respectively. Since the highest contaminant concentrations and the greatest contaminant concentration variability are expected in the cohesive sediment areas, all of the cohesive sediment areas are included. The non-cohesive areas are approximately equally divided among high and low TOC elements. The distribution of sampling areas among the sediment types is shown in Table E-1. Maps indicating the locations of the sampling areas within each of the reaches are presented on Figure E-3 and coordinates digitized from these maps are presented in Table E-2.

Quantification of average concentrations within a grid element requires multiple samples. Five sediment samples will be collected from random locations within each element or area. As a means of minimizing cost, all samples taken within a sampling area will be composited.

Sampling Procedures and Sample Analyses

Sampling locations listed in TableE- 2 and shown on the enclosed map have been selected based on sediment characteristics (TOC and grain size). Approximately half of the locations selected for coring are in fine grained, high TOC areas. Hopefully this will increase the success rate of obtaining cores. Where possible, push cores will be used to obtain samples to a depth of at least 40 centimeters. The classification of sampling locations as cohesive, high TOC - noncohesive or low TOC - noncohesive may provide a basis for assessing the appropriate coring technique (push or vibra-core). Core tubes will be sealed as quickly as possible after collection to minimize exposure of the sediment sample to oxygen.

In areas where cores can not be collected, grab samples from approximately the upper 5 centimeters will be collected. The 5 centimeter depth for grab samples corresponds to the depth of the top slice that will be analyzed from sediment cores. The volume of sample collected will be sufficient to fill the sample container and eliminate any headspace of air in the sample container. Sample handling and decontamination procedures will be the same as for the release characterization. Some analytical procedures for these samples will differ from the release characterization in order to reach the lower detection limits required for subsequent modeling analyses.

Water temperature and depth of water at the sample location will be recorded.

A visual characterization of the surficial sediment of each core will be noted. Cores will then be sectioned vertically as indicated in Table E-3.

The zero to five centimeter depth interval from each of the five cores obtained in a sampling area will be composited. Similarly the 5 to 10 cm depth intervals will be composited, as will the 10 to 20 cm intervals, 20 to 30 cm intervals, and the 30 to 40 cm intervals. A separate study will be conducted in advance of the sediment sampling program to evaluate the appropriateness of compositing samples that will be analyzed for volatile organics.

The proposed analyses for the composite samples are listed in Table E-4 with detection limits for the chemicals to be modeled. Samples will be split and seperate subsamples will be used for contaminants and solids analyses.

In one sampling area in the facility reach additional shallow cores will be collected for determination of pore water concentrations. Nine 4 inch cores, sixteen 3 inch cores or twenty two 2.5 inch cores will be collected and the top 5 centimeters composited. A bulk subsample will be analyzed in accordance with Table E-4, and the remainder will be centrifuged. Centrifuge vessels will be filled so that no head space is present. This will prevent the loss of volatile organics from the sample. The centrate will be analyzed for the metals and organics listed in Table E-4, as well as organic carbon.

In-Situ Resuspension Potential of Cohesive Sediments

The in-situ resuspension potential of fine-grained, cohesive sediments will be measured using a "shaker" and following the procedure used in previous USEPA projects in the Lower Fox River and Green Bay (Tsai and Lick, 1986; Xu, 1991). Surficial sediment cores will be collected using a 5-inch- diameter push corer. The penetration depth of the corer will be about 6 inches. The coring tube will be attached to a 15-foot-long pole so that cores can be collected from a boat. The sediment-water interface of each core cannot vary vertically by more than 0.5 inch; any core that does not meet this criterion will be discarded and another core will be collected to replace it.

In the facility reach, a total of ten sampling locations will be established on five transects (spaced 400 feet apart). Two sampling locations will be established on each transect — one near the right bank

and the other near the left bank. These transects will correspond to the transect locations used for bathymetric/sediment mapping. Sampling locations will be established only in areas of fine-grained, cohesive sediments. In the extended upstream, upstream, downstream, and extended downstream reaches, two sampling locations will be established on each 0.5-mile transect; again, one will be near the right bank and the other near the left bank. Three sample cores will be collected at each sampling location. Each core will be used to determine the resuspension potential at one of three shear stress values — one core will be tested at 5 dynes/cm^2, the second at 7 dynes/cm^2, and the third at 9 dynes/cm^2.

After collecting the cores at a location, each core will be prepared for the shaker test. The initial suspended solids concentration in the overlying water column of the core will be measured by withdrawing 50 ml of water with a syringe. This 50-ml sample will then be filtered through a 2-mm filter which has been numbered and preweighed. Water will then be removed from the coring tube until a 3-inch column of water remains above the sediment-water interface. The core will then be placed in the shaker, and the height of the core in the shaker will be adjusted so that the shaker grid is one inch above the sediment-water interface when the grid is at the bottom of its stroke. The shaker oscillating period will be set to the value needed to generate the shear stress desired and the shaker will be run for 10 minutes. The core will be removed from the shaker at the end of the test. The final suspended solids concentration will then be measured in the same way as the initial concentration (by filtering a 50-ml water sample through a pre-weighed filter). Each filter will be placed in a separate Petri dish for storage and transport. All filters will be dried at 105°C for one hour before final weighing and determination of the suspended solids concentration.

E.4.4 Methods and Analyses for Routine Water Column Monitoring

Routine water column monitoring involves *establishing monitoring stations* and *collecting samples*.

Establishing Monitoring Stations

Routine water column monitoring will be conducted weekly at all six monitoring (sampling) stations shown in Figure E-1. (The procedures for installing and operating the monitoring stations were discussed in Section E.4.2.)

Collecting Samples

At each station, water will be pumped from mid-depth at mid-channel and a 1-liter sample of unfiltered water will be collected. One hundred liters of water will be pumped through a 0.45-mm filter and a 1-liter sample of the filtrate will be collected. Filtering a large volume of water is necessary to reduce the impact of contaminant loss to the filter on contaminant concentrations in the filtrate. Sample containers appropriate for the contaminants included in the study will be used. Samples will be chilled to 4°C and transported to the laboratory for analysis. Each sample will be assigned a unique sample designation which will identify the sampling location, date, and time.

To collect river water samples from mid-depth, a boat will be positioned over the sampling location by measuring the distance from the bank or by using electronic distance measuring devices. The boat will be equipped with discrete water samplers (e.g., Kemmerer samplers, Alpha bottles) and a pump (with components that will not cause interference in the analyses to be performed on the sample). The sampler must be constructed of material consistent with the type of analyses to be performed on the sample (e.g., glass containers for organics, plastic for metals). A field crew of two people, familiar with boating safety and equipped with personal floatation devices and other necessary personal protective equipment (as specified in the site Health and Safety Guidelines, Volume 3 of the RCRA Facility Investigation Proposal), will attend the boat at all times.

The total depth of the water column at the sampling location will be measured by dropping a weighted, metered line to the bottom of the river. Total water depth will be recorded in the field log, along with the date, operators, sampling location, weather conditions, and any other information required so that the sampling effort could be duplicated based on the information in the field log.

If discrete samples are collected, the sampler will be lowered to one-half the total depth of the river at the sampling location, allowed to equilibrate with the surrounding water, stoppered, and returned to the surface. The sample will be poured into the sampling containers, filling the volatile organic sample container first (if required) to minimize loss of volatile compounds from the sample. Samples will be labelled, preserved as required for the analytical protocols to be performed, and shipped overnight or delivered to the analytical laboratory under documented custody procedures (outlined in the Quality Assurance Documents, Volume 2 of the RCRA Facility Investigation Proposal). Sample numbers will be consistent with the field sampling plan.

If large volumes of sample are collected using the pump, the intake line will be weighted to descend to one-half the total depth of the water column. The pump will be turned on and purged for one minute before sample collection begins. An equipment blank sample will be collected first to quantify any residual contamination existing in the pump or lines. The equipment blank sample will be handled in the same way as all other samples (i.e., collected in sampling containers, preserved, and shipped with the field samples to the laboratory). The remaining sample volume will be collected in intermediate containers consistent with the analyses to be performed on the samples (e.g., plastic for metals, glass for organics).

Equipment decontamination will be consistent with the types of contaminants expected to be present in the samples. The pump, remote sampler, and intermediate containers will be decontaminated after every sample and the decontamination fluids will be retained for proper disposal.

For samples that require filtering, this procedure can be performed either on the boat (using a portable generator and filtration device) or in the field laboratory (at the facility); the decision to filter samples will be made at the discretion of the field sampling coordinator. For the water samples to be collected as part of routine water quality monitoring, 100 liters of sample will be filtered through a 0.45 mm filter to collect one liter of sample for analysis. Samples will be preserved, labelled, sealed, and delivered to the laboratory as specified in the field sampling plans.

E.4.5 Analysis of Data to Support River Modeling

The data to be analyzed in order to support river modeling include:

- *river geometry* data;
- *bed sediment mapping* data;
- *suspended solids/flow relationship* data;
- temporal and spatial *water column contaminant concentrations*;
- temporal and spatial *sediment contaminant concentrations*.

In addition, analyses are needed for:

- contaminant partitioning;
- calculating resuspension parameters; and
- determining suspended solids and contaminant profiles during storm events.

This section presents the methods and analyses for each of these activities.

Analyzing the River Geometry Data

Bathymetry data will be used to determine the water depths needed as input to the hydro-dynamic model. Transect lengths and locations will be used to define channel geometry in the upstream and downstream reaches. The geometry data also can be used to determine relationships between channel cross-sectional area/depth and flow rate. These relationships can then be used in the chemical fate model.

Analyzing the Bed Sediment Mapping Data

A bed sediment map detailing areas of cohesive and non-cohesive sediments will be constructed from Cranston to Pawtuxet Cove Dam. The results from the bed sediment characteristics study (described earlier) will be used to assign appropriate values to model parameters for non-cohesive sediment transport (e.g., D_{50} and D_{90}). Data on the spatial variation of TOC will be used in the chemical fate model.

Determining the Suspended Solids-Flow Relationship

All available suspended solids data will be analyzed to generate a relationship between concentration and flow rate. This relationship can then be used to provide sediment loading at the upstream model boundary for periods in which data are not available. Analysis of spatial trends along the reach from Cranston to Pawtuxet Cove Dam can be performed using the concentration-flow rate relationships developed for all three sampling locations.

Temporal and Spatial Water Column Contaminant Concentrations

The contaminant monitoring data will be presented graphically to define the temporal and spatial trends in concentration. These patterns will provide insight into the location of potential sources as well as the effect of factors such as river flow on water column concentrations. These data can help relate the mass of contaminants transported past each of the monitoring stations to the magnitude of the river flow. Additionally, these data will be used to calibrate the chemical fate model by comparing these data to calculated concentration profiles.

Contaminant Partitioning

The distribution between dissolved and sorbed phases is an important factor in the ultimate fate of an organic chemical or metal. Phase II monitoring data will be analyzed to evaluate the partitioning characteristics of the contaminants of concern. A partition coefficient describes the distribution of a contaminant between a sorbed and dissolved phase. The fraction of a contaminant in the dissolved form is given by the equation:

$$f_d = 1/(1+\pi m) \quad (1)$$

where

f_d = fraction dissolved
π = partition coefficient
m = suspended solids concentration

Partition coefficients in a specific water body can be estimated by:

$$\pi = f_{oc} K_{oc} \quad (2)$$

where

f_{oc} = ratio of organic carbon to suspended solids
K_{oc} = organic carbon partition coefficient

An analysis of the monitoring data will provide a basis for the fate model's representation of the relationship between partition coefficients for individual contaminants and site-specific suspended solids and organic carbon data.

An analysis of the monitoring data will provide a basis for the fate model's representation of the relationship between partition coefficients for individual contaminants and site-specific suspended solids and organic carbon data.

Statistical Analysis of Sediment Contaminant Data

A critical component of the contaminant transport and fate model is the description of the existing three-dimensional sediment bed concentration profiles of the contaminants to be modeled. An accurate estimation of the average concentration for each reach of the river depends on both the *selection of sampling locations* and the *statistical analysis of analytical results*.

Selection of Sampling Locations. Concentrations of metals and organic chemicals are correlated to the grain size of the sediments — the variability of concentrations on fine-grained sediments is higher than those on coarse-grained sediments. Because of this higher variability, more samples are needed in order to estimate confidently average concentrations for fine-grain sediment samples. Thus, sampling locations must be selected on the basis of sediment bed characteristics. Average concentrations for different sediment types can be calculated and used to develop an average concentration for a sub-reach based on the weighted composition of different sediment types within each sub-reach.

Statistical Analysis of Analytical Results. Calculation of average concentrations can be complicated by values reported below detection limits. Various statistical techniques are available to overcome this problem; these include regression of a probability distribution and maximum likelihood estimate (Aitchison, 1981) techniques. USEPA Region V has applied some of these techniques in an analysis of PCBs in Green Bay, Wisconsin. The selection of the most appropriate technique is influenced by the range in detection limits and their relation to detected concentrations. Based on the results from the Phase II bed sediment contaminant data, the most appropriate statistical techniques consistent with RCRA and the Order will be recommended and discussed with USEPA Region I.

After calculating average contaminant concentrations in each sampling area, concentrations in unsampled grid elements will be interpolated based on gradients in contaminant concentrations and sediment bed characteristics. The interpolation will be evaluated based on available data obtained as part of the release characterization. A second analysis will be conducted to further evaluate the validity of the initial interpolation procedure. In this case interpolated contaminant concentrations from approximately 50 grid elements that were not sampled will be treated as field data from a second interpolation. After the second interpolation, a comparison will be made between original field data and interpolated contaminant concentration in grid elements where samples were actually obtained. If the interpolation procedure is judged unreliable, additional sampling will be recommended.

Calculation of Resuspension Parameters

Calculation of Resuspension Parameters

The in-situ resuspension potential of fine-grained, cohesive sediments will be measured in a shaker study (described in Chapter 4). The amount of cohesive sediment resuspended is given by the equation (from Gailani, et al., 1991):

$$\epsilon = A\left[\frac{\tau - \tau_0}{\tau_0}\right]^3 \quad ,\tau > \tau_0 \qquad (3)$$

$$= 0 \qquad ,\tau \leq \tau_0$$

where

- ϵ = net amount of resuspended sediment per unit surface area (gm/cm^2)
- A = a site-specific constant
- τ = shear stress (dynes/cm^2) generated by currents
- τ_0 = effective critical shear stress (about 1 dyne/cm^2)

Results of the shaker study will be used to determine the value of the in-situ resuspension potential parameter, A, in Equation (3) within the cohesive sediment areas. The shaker uses an oscillating grid to resuspend sediment in a coring tube by generating a turbulent shear stress at the sediment-water interface. The shaker has been calibrated to an annular flume in which the shear stress has been measured accurately, and a relationship has been developed between shaker oscillation period and equivalent shear stress. Spatial variability of the resuspension potential parameter, A, along the 4.5-mile reach being considered in the present study also will be analyzed.

Suspended Solids and Contaminant Profiles During Storm Events

Suspended sediment hysteresis is a well-known phenomenon that occurs during a river flood. This phenomenon involves an initial steady increase of sediment concentration as the flow rate increases. After the flood peak, the solids concentration decreases much more quickly than the river flow subsides. The primary cause of the hysteresis effect is armoring of the sediment bed, a process which limits the amount of sediment that can be resuspended for a specific flow rate/bottom shear stress. An armored sediment bed is created by particle size sorting and interparticle cohesion during the resuspension process. Erosion of the bed is discontinued, at a specific bottom shear stress, once the bed is armored.

Data collected during high flow events will be analyzed to determine the significance of the hysteresis effect in the Pawtuxet River. These data also will be used to calibrate and verify the sediment transport model for periods of high flow.

E.4.6 Developing and Calibrating the Hydrodynamic Model

Lateral variations in the Pawtuxet River sediment bed structure require a two-dimensional, vertically-integrated hydrodynamic model for meaningful simulation of river conditions. Fine-grained sediments generally are found in shallow nearshore areas, while the sediment bed in the deeper central channel is composed primarily of sands and gravels. The river velocity (and, hence, bottom shear stress) also will vary laterally due to bathymetry changes. Thus, use of a two-dimensional hydro- dynamic model is required so that accurate estimates of bottom shear stress in areas of cohesive sediment can be calculated.

The numerical grid for the hydrodynamic model will extend from an upstream limit at the USGS Cranston gauge to a downstream boundary at Pawtuxet Cove Dam. This modeling domain ensures the proper specification of inflow and outflow rates. An orthogonal, curvilinear grid will be used in order to represent river geometry accurately. A minimum of four segments will be used to discretize the river spatially in the lateral direction. Variations in bathymetry and sediment bed composition can be accounted for realistically with this resolution.

The hydrodynamic model will be calibrated and verified using stage height data obtained at the three gauge stations (Cranston, facility, Pawtuxet). The downstream stage height, along with the measured upstream flow rate, will be used as input to the model. Predicted stage heights at Cranston and the facility will be compared with observations for three flow regimes (low, medium, and high).

E.4.7 Developing and Calibrating the Sediment Transport Model

The Ziegler-Lick sediment transport model (SEDZL) will be applied to the Pawtuxet River. This model was developed for the USEPA specifically to account for the resuspension, deposition, and fate of cohesive sediments. The model also includes a non-cohesive sediment transport component. SEDZL has been used to study the sediment transport processes in a number of different aquatic systems, including the Venice (Italy) Lagoon, Trenton Channel of the Detroit River, Lower Fox River/Green Bay, Buffalo River, Saginaw River, Lake Erie, and Santa Barbara Channel. Sediment transport data from the Lower Fox River were used to obtain excellent numerical results in a calibration/verification of SEDZL (Gailani, et al., 1991).

The sediment transport model is coupled directly to the hydrodynamic model and uses the same numerical grid. The model will be calibrated and verified using suspended sediment concentration data collected during low, medium, and high flow rates. At least two flood events will be modeled — one for calibration and the other for verification. The calibrated/verified sediment transport model

will then be used to estimate the effects of the 100-year flood of the Pawtuxet River, especially in the facility reach. Areas of erosion and deposition, along with depth changes, will be predicted by the model for the 100-year flood.

The sediment transport model will be coupled to the chemical fate model. Appropriate data from the sediment transport model (e.g., deposition and resuspension rates) will be transferred to the chemical fate model so that the effects of sediment transport processes are incorporated into the chemical fate model.

E.4.8 Developing and Calibrating the Chemical Fate Model

A chemical fate model — WASTOX (Connolly and Winfield, 1983) — will be applied to a section of the Pawtuxet River from the USGS gauge at Cranston to the Pawtuxet Cove Dam and will be used to analyze the fate of selected contaminants. The WASTOX model was developed for the USEPA by HydroQual personnel. The model's processes are shown in Figure E-4. In addition to transport, the modeling framework includes adsorption-desorption, biodegradation, hydrolysis, acid-base equilibria, photolysis, and volatilization.

Generally, adsorption to suspended or bed sediment is viewed as a rapid process relative to the other processes affecting a toxic chemical. Local instantaneous equilibrium is assumed. For organic chemicals whose adsorption is classified as hydrophobic bonding, equilibrium adsorption at environmentally relevant concentrations is linear to dissolved chemical concentrations (Connolly, et al., 1983; Karickhoff, 1984) and may be written as:

$$r = \pi c \qquad (4)$$

where

r = sorbed chemical concentration (M/M)
π = the adsorption partition coefficient (L^3/M)
c = dissolved chemical concentration (M/L^3)

For non-hydrophobic bonding, linearity also is observed frequently, but is complicated by chemical speciation and other sorbant- and solution-phase chemistry.

For organic chemicals, laboratory studies have shown that the partition coefficient is related to the hydrophobicity of the chemical and the organic matter content of the sediment. Normalization of the partition coefficient by the organic carbon content of the sediment has been shown to yield a coefficient, K_{oc}, which is relatively independent of other sediment characteristics or geographic origin (Karickhoff, 1981). K_{oc} has been correlated successfully with the water solubility of the chemical

The partitioning of metals is complicated by speciation reactions that are functions of pH and the concentrations of organic and inorganic ligands. In general, it is the metal-hydroxide species which sorbs to mineral and organic particles, so partitioning tends to increase with increasing pH. In sediments, metals typically are sequestered as metal-sulfide precipitates and sorb significantly to particles only where the molar concentration of the metal exceeds the molar concentration of sulfide. If a metal is modeled, speciation will not be considered explicitly — partition coefficients will be calculated from the dissolved and particulate metal concentrations observed.

Generally, biodegradation is assumed to follow Michaelis-Menton enzyme kinetics and can be described mathematically as:

$$\frac{dc}{dt} = - \frac{V_{max} c}{K_m + c} B \qquad (5)$$

where

V_{max} = maximum rate of degradation (M_c/M_B-T)
K_m = half-saturation constant (M_c/L^3)
B = bacterial activity (M_B/L^3)
t = time (T)
M_c = mass of chemical
M_B = mass of bacteria

In river systems, the chemical concentration typically is much less than the half-saturation constant, and equation (5) simplifies to:

$$\frac{dc}{dt} = - \frac{V_{max}}{K_m} cB = -K_b cB \qquad (6)$$

Rather than modeling the bacteria directly, a constant bacterial activity is assumed. Equation (6) then simplifies to a first-order reaction rate.

The flux, j, of a toxic chemical across the air-water interface due to volatilization from surface waters is described by the following equation:

The flux, j, of a toxic chemical across the air-water interface due to volatilization from surface waters is described by the following equation:

$$j = -K_{OL}(c - P/H) \quad (7)$$

where

j = flux ($M/L^2 - T$)
K_{OL} = overall mass transfer coefficient (L/T)
P = partial pressure of the chemical in the atmosphere (ATM)
H = Henry's constant (L^3 - ATM/M)

For most chemicals, the partial pressure in the atmosphere is zero, and equation (7) reduces to:

$$j = -K_{LC}c \quad (8)$$

The rate of transfer of a chemical (given by K_{OL}) is controlled both by properties of the chemical and by conditions at the air-water interface. Its value is computed using the two-film theory:

$$\frac{1}{K_{OL}} = \frac{1}{K_L} + \frac{RT}{HK_G} \quad (9)$$

where

K_L = liquid mass transfer coefficient (L/T)
K_G = gas mass transfer coefficient (L/T)
R = the gas constant (ATM - L^3/M - $^\circ$K)
T = absolute temperature ($^\circ$K)

The liquid and gas transfer coefficients in equation (9) depend on turbulence at the interface, temperature, and properties of the chemical (such as diffusivity). The liquid mass transfer coefficient, K_L, is calculated from the following equation:

where

$$K_L = \left[\frac{Du}{h}\right]^{1/2} \quad (10)$$

D = molecular diffusivity of the chemical (L^2/T)
u = river velocity (L/T)
h = water column depth (L)

The gas mass transfer coefficient (K_G) does not vary greatly in river systems because wind effects are minimal; its value is assumed to be constant at about 100 m/day.

Hydrolysis is a reaction in which a molecular bond of the chemical is cleaved and a new bond is formed with the hydrogen and hydroxyl components of a water molecule. Hydrolytic reactions usually are catalyzed by an acid and/or base. In general, the overriding factor affecting hydrolysis at a given temperature is the hydrogen or hydroxide concentration (Wolfe, 1980). The equation used to describe hydrolysis is:

$$\frac{dc}{dt} = -K_H [H^+] + K_{H20} + K_{OH} [OH^-]) c \quad (11)$$

where

K_H = acid hydrolysis rate constant ($L^3/M - T$)
KH_2O = neutral hydrolysis rate constant (1/T)
K_{OH} = alkaline hydrolysis rate constant (L^3/M-T)
$[H^+]$ = hydrogen ion concentration (M/L^3)
$[OH^-]$ = hydroxide ion concentration (M/L^3)

The model does not compute hydrogen or hydroxide concentration; instead, these values are input to the model assuming that their concentrations are unaffected by the hydrolysis reaction (because of the low concentration of the toxic chemical).

Photodegradation (photolysis) is the transformation or degradation of a compound that results directly from the absorption of light energy. The amount of photolysis is a function of the quantity and wavelength distribution of incident light, the light absorption characteristics of the compound and the efficiency at which absorbed light produces a chemical reaction. Two types of photolysis are defined by the mechanism of energy absorption. *Direct* photolysis is the result of direct absorption of photons by the chemical modeled. *Indirect* (or "sensitized") photolysis is the result of energy transfer to the chemical from some other molecule that has absorbed radiation. A quantitative framework for predicting direct photolysis from the incident light and the characteristics of the chemical (Zepp &

Cline, 1977) has successfully predicted the photodecomposition of chemicals in pure water and has been incorporated in WASTOX.

The river will be represented in the model by three segments across the width and 26 divisions in the longitudinal direction, for a total of 78 water column segments. This segmentation represents an aggregation of the 360 element grid discussed as part of the sediment sampling plan. Initial model runs were attempted with a 360 water column segment model identical to the 360 element sampling grid, however, solution times were excessive. Solution times in the 78 water column segment model are reduced by two factors. The first factor is simply the ratio of the number of segments and the second is based on the increase in the minimum integration step dictated by the finite difference solution scheme.

The contaminant fate model will be include a vertical column of segments under each water column segment. The number of sediment segment layers and the thickness of each will be based on the vertical concentration profiles of the sediment contaminants. Thinner layers will be used to accurately resolve the observed profiles where vertical gradients are most significant and thicker layers will be used to represent well mixed portions of the sediment. (In other studies, three layers of sediment segments have produced satisfactory results.) The total depth of the sediment segments will be based on both the sediment concentration profiles and the results of the sediment transport model, which will indicate the depth of sediment which could potentially influence overlying water concentrations during resuspension events. Sediment transport analyses conducted to date indicate that maximum depths of resuspension in local areas would be near 16 cm under a 100-year flood. Based on this information the current sampling plan, to a depth of 40 cm will be sufficient.

In addition to suspended solids, the model will include concentrations of contaminants entering the upstream boundary, as well as estimates of inputs to the river within the modeled reach from sources such as groundwater inflow. Interactions between the sediment bed and the water column will be included. The period for which routine water column monitoring data are available will be the time period used for model calibration. Sediment bed contaminant concentrations will be assigned for each sediment segment based on the Phase II bed contaminant sampling results. Calibration will involve adjusting the coefficients that describe the relevant transformation processes to achieve agreement between measured and computed water column contaminant concentrations.

The adjustment of coefficients will be limited to ranges reported in the literature.

E.4.9 Sensitivity Analyses

Sensitivity analyses will be performed to evaluate the effect of uncertainty in model input parameters on model results and conclusions. Sensitivity to specific model input parameters will be judged by the change in computed concentrations resulting from variation of model input parameters within reasonable limits. Evaluation of the model sensitivity to input parameters will help identify the level of precision required in the assignment of model parameter values.

E.4.10 Projecting Future Contaminant Concentrations

The calibrated contaminant fate model can serve as a management tool — it will be used to evaluate the response of contaminant concentrations in the river to possible remediation alternatives. The model also would project the response of water column contaminant concentrations to changes in inputs (such as groundwater).

E.5 SUMMARY

A coupled hydrodynamic/sediment transport/chemical fate model will be developed and calibrated/verified during Phase II. The model domain will extend from Cranston to the Pawtuxet Cove Dam with adequate resolution for the accuracy requirements of this study. A two-dimensional, vertically-integrated hydrodynamic model will be used to account for lateral variations in river velocities. The sediment transport model will simulate the resuspension, deposition and fate of cohesive and non-cohesive sediments. All significant processes will be included in the chemical fate modeling framework. Historical data will be added to Phase I data. Phase II field study results will be added to the data base as they become available. Stage height data will be used to calibrate and verify the hydrodynamic model. A bed sediment map will be generated from the results of the bed characterization study. The in-situ resuspension potential of cohesive sediments will be measured. Contaminant concentration data in the water column and the sediment bed will be analyzed to determine spatial and temporal trends. Storm surveys will be conducted to provide suspended solids and contaminant data during high flow events. The available data will be used to calibrate and verify all three numerical models. Erosional effects of a 100-year flood will be determined using the hydrodynamic and sediment transport models. The calibrated/verified chemical fate model can be used to predict the effects of various remedial options. The schedule for these tasks is presented in Figure 7-2

REFERENCES

Aitchison, J. and Brown, J.A.C. *The lognormal distribution.* London: Cambridge University Press, 1981.

Connolly, J.P., Armstrong, N.E., and Miksad, R.W. Adsorption of hydrophobic pollutants in estuaries. *Journal of Environmental Engineering, ASCE*, 1983, *109(1)*, 17-35.

Connolly, J.P. and Windfield, R.P. *WASTOX, a framework for modeling the fate of toxic chemicals in aquatic environments, Part 1: exposure concentration.* U.S. Environmental Protection Agency, Gulf Breeze, FL, 1983.

Gailani, J., Ziegler, C.K., and Lick, W. The transport of suspended solids in the Lower Fox River. *Journal of Great Lakes Research*, 1991 (in press).

Hassett, J.J., Means, J.C., Barnwart, W.L., and Wood, S.G. *Sorption properties of sediments and energy-related pollutants.* U.S. Environmental Protection Agency, EPA-600/3-80-041, 1980.

Karickhoff, S.W. Semi-empirical estimation of sorption of hydrophobic pollutants on natural sediments and soils. *Chemosphere*, 1981, *10*, 833-846.

Karickhoff, S.W. Organic pollutant sorption in aquatic systems. *Journal of Hydraulic Engineering, ASCE*, 1984, *110(6)*, 707-735.

Quinn, J.G., Hoffman, E.J., Latimer, J.S., and Carey, C.G. *A study of the water quality of the Pawtuxet River: Chemical monitoring and computer modeling of pollutants.* Providence, RI: University of Rhode Island, Graduate School of Oceanography, 1985.

Rao, P.S.C., Davidson, J.M., Berkheiser, V.E., Ou, L.T., Street, J.J., Wheeler, W.B., and Yuan, T.L. *Retention and transformation of selected pesticides and phosphorus in soil-water systems: A critical review.* U.S. Environmental Protection Agency, EPA-700/3-82-060, 1982.

Rhode Island Statewide Planning Program and Rhode Island Department of Health. *Water quality management plan for the Pawtuxet River Basin.* July 1977.

Schwarzenbach, R.P. and Westall, J. Transport of non-polar organic compounds from surface water to groundwater. *Environmental Science and Technology*, 1981, *15(11)*, 1360-1367.

Tsai, C.H. and Lick, W. A portable device for measuring sediment resuspension. *Journal of Great Lakes Research*, 1986, *12*, 314-321.

U.S. Geological Survey. *Guidelines for determining flood flow frequency.* Bulletin 17B, 1982.

U.S. Geological Survey. *Rhode Island streams — 1978-88, An update on water quality conditions.* Water Resources Investigations Report 90-4082, 1990.

Wolfe, N.L. Determining the role of hydrolysis in the fate of organics in natural waters. In R. Haque, (ed.) *Dynamics, exposure and hazard assessment of toxic chemicals.* Ann Arbor, MI: Ann Arbor Science, 1980, 69–110.

Xu, Y.J. *Transport properties of fine-grained sediments.* Unpublished doctoral dissertation, University of California at Santa Barbara, 1991.

Zepp, R.G. and Cline, D.M. Rates of direct photolysis in aquatic environment. *Environmental Science and Technology*, 1978, *11(4)*, 359-366.

TABLE E-1. DISTRIBUTION OF SAMPLING AREAS			
	Number of Sampling Areas		
Reach	Cohesive Sediment	High TOC Non-Cohesive Sediment	Low TOC Non-Cohesive Sediment
Upstream	1	5	3
Facility	15	6	6
Downstream	8	4	3

TABLE 2A. SAMPLING LOCATIONS IN AREAS CHARACTERIZED BY COHESIVE SEDIMENTS									
Easting	Northing	Easting	Northing	Easting	Northing	Easting	Northing	Easting	Northing
521967.6	247181.7	522019.0	247198.4	522075.3	247217.1	522125.1	247234.3	522170.8	247250.8
523898.9	248432.2	523919.9	248465.7	523940.9	248507.5	523963.7	248550.2	523988.3	248594.6
524020.8	248650.8	524040.8	248674.5	524061.1	248700.2	524081.8	248724.8	524104.0	248752.9
523943.4	248708.7	523965.5	248740.6	523988.1	248768.2	524009.8	248795.7	524030.8	248823.4
524135.2	248790.3	524153.1	248806.8	524173.2	248823.9	524192.7	248839.4	524215.2	248854.8
524250.5	248874.9	524271.8	248885.0	524291.8	248895.2	524313.1	248905.1	524337.6	248915.8
524376.7	248928.4	524403.2	248934.3	524426.8	248939.3	524451.7	248944.4	524481.8	248948.9
524662.4	249050.7	524689.1	249060.1	524714.6	249068.2	524737.1	249077.1	524762.1	249085.8
524655.9	249063.9	524686.4	249072.3	524713.1	249082.2	524735.7	249091.9	524759.2	249099.5
524792.1	249112.8	524819.0	249123.8	524842.6	249134.1	524869.3	249143.6	524895.6	249156.0
524966.7	249103.5	524988.4	249114.8	525010.9	249129.7	525038.4	249144.7	525064.3	249157.8
524960.3	249121.7	524980.8	249133.2	525003.4	249148.3	525033.4	249161.3	525058.1	249174.8
525104.4	249175.4	525130.5	249180.9	525156.4	249186.3	525187.8	249192.0	525217.1	249196.4
525101.1	249190.4	525131.1	249198.4	525161.0	249204.1	525185.9	249208.4	525212.1	249213.4

525387.3	249287.7	525415.6	249292.4	525444.9	249301.2	525471.7	249308.7	525495.8	249316.7

TABLE 2A. SAMPLING LOCATIONS IN AREAS CHARACTERIZED BY COHESIVE SEDIMENTS

Easting	Northing	Easting	Northing	Easting	Northing	Easting	Northing	Easting	Northing
526623.9	248958.2	526648.6	248943.1	526673.4	248925.8	526706.6	248907.4	526740.1	248886.5
526679.2	249024.1	526697.8	249008.4	526721.3	248995.9	526747.1	248980.8	526771.5	248968.1
528189.8	249086.6	528230.2	249062.2	528264.1	249037.3	528285.0	249002.8	528301.1	248973.2
528312.3	248928.6	528311.8	248898.8	528313.5	248875.6	528312.4	248846.1	528312.9	248823.9
528314.5	248781.1	528310.6	248744.6	528304.4	248700.2	528303.7	248646.9	528302.7	248592.2
529105.1	247910.1	529162.8	247900.5	529233.8	247889.1	529288.3	247884.1	529340.6	247881.2
529397.1	247896.9	529439.4	247917.7	529479.4	247950.3	529508.4	247979.1	529545.4	248017.3

TABLE 2B. SAMPLING LOCATIONS IN AREAS CHARACTERIZED BY HIGH TOC, NON-COHEISVE SEDIMENTS									
Easting	Northing	Easting	Northing	Easting	Northing	Easting	Northing	Easting	Northing
519913.4	247178.0	519951.2	247207.2	519983.5	247233.1	520026.5	247263.3	520062.5	247291.7
516123.4	245780.4	516160.8	245807.1	516187.5	245834.3	516203.8	245864.3	516222.1	245899.1
515967.4	244528.4	515971.2	244566.8	515974.5	244613.2	515977.6	244658.1	515981.8	244695.4
521950.3	247207.3	522004.5	247230.9	522061.9	247252.8	522108.4	247271.5	522157.0	247290.9
523818.3	248489.8	523841.3	248531.2	523863.9	248568.8	523888.9	248611.7	523909.1	248652.3
523987.7	248675.5	524007.0	248705.6	524031.4	248737.3	524053.7	248763.9	524070.7	248786.4
524082.6	248851.9	524103.9	248867.8	524124.0	248885.7	524146.5	248900.9	524171.2	248921.2
524072.8	248866.3	524094.9	248885.0	524115.0	248902.1	524136.9	248917.0	524162.2	248936.2
524680.6	248975.9	524708.2	248983.7	524735.5	248993.6	524757.8	249001.5	524782.3	249014.1
525546.7	249236.0	525574.0	249243.0	525600.6	249249.5	525627.1	249256.4	525661.0	249261.8
526252.1	249330.2	526278.1	249329.5	526307.4	249319.8	526333.3	249306.3	526354.5	249293.0
527561.7	249365.8	527602.6	249330.4	527657.7	249288.4	527706.9	249268.2	527753.7	249250.2
527580.4	249411.9	527630.9	249381.5	527690.9	249345.2	527741.6	249317.8	527788.8	249297.2
529391.3	248037.2	529444.8	248062.1	529485.9	248088.1	529516.4	248116.9	529549.6	248150.9

TABLE 2C. SAMPLING LOCATIONS IN AREAS CHARACTERIZED BY LOW TOC, NON-COHESIVE SEDIMENTS									
Easting	Northing	Easting	Northing	Easting	Northing	Easting	Northing	Easting	Northing
516150.3	245739.0	516190.8	245774.1	516212.1	245803.8	516237.5	245835.2	516258.3	245873.2
515053.2	243130.1	515093.0	243111.0	515135.3	243098.9	515175.8	243090.6	515225.8	243089.9
523861.6	248461.2	523885.4	248507.0	523906.0	248541.7	523926.6	248583.1	523948.6	248621.8
523955.8	248700.7	523976.7	248728.3	524000.9	248758.6	524021.2	248785.1	524043.1	248811.3
524108.3	248822.6	524132.4	248840.9	524151.5	248856.6	524174.4	248872.2	524197.3	248888.5
524358.8	249005.6	524382.9	249010.1	524409.9	249015.3	524437.2	249019.4	524467.1	249026.1
524516.4	248985.0	524543.4	248991.9	524569.5	248996.0	524600.1	249003.2	524626.2	249007.5
525543.9	249275.5	525569.9	249280.6	525592.8	249284.7	525617.8	249289.8	525647.1	249294.2
525852.4	249328.2	525890.0	249337.8	525919.9	249345.2	525958.4	249352.2	525990.3	249361.5
527572.4	249383.3	527617.8	249354.9	527679.5	249318.1	527727.5	249295.9	527768.2	249272.9
528349.0	248784.5	528349.2	248738.8	528350.2	248701.2	528347.8	248647.7	528348.6	248596.1

TABLE E-3.	
Interval	Depth (cm)
1	0 - 5
2	5 - 10
3	10 - 20
4	20 - 30
5	30 - 40

TABLE E-4.	
Analyses Total Solids Fraction (weight of dry sample/weight of wet sample) pH Organic Carbon Acid Volatile Sulfide	
	Detection Limit (mg/kg)
Chlorobenzene	0.01
Toluene	0.01
Naphthalene	0.01
PCB congeners (mono through deca)	0.10
Tinuvin 328	0.15
Simultaneously Extracted Metals	
Zinc	0.30
Copper	0.30
Silver	0.50

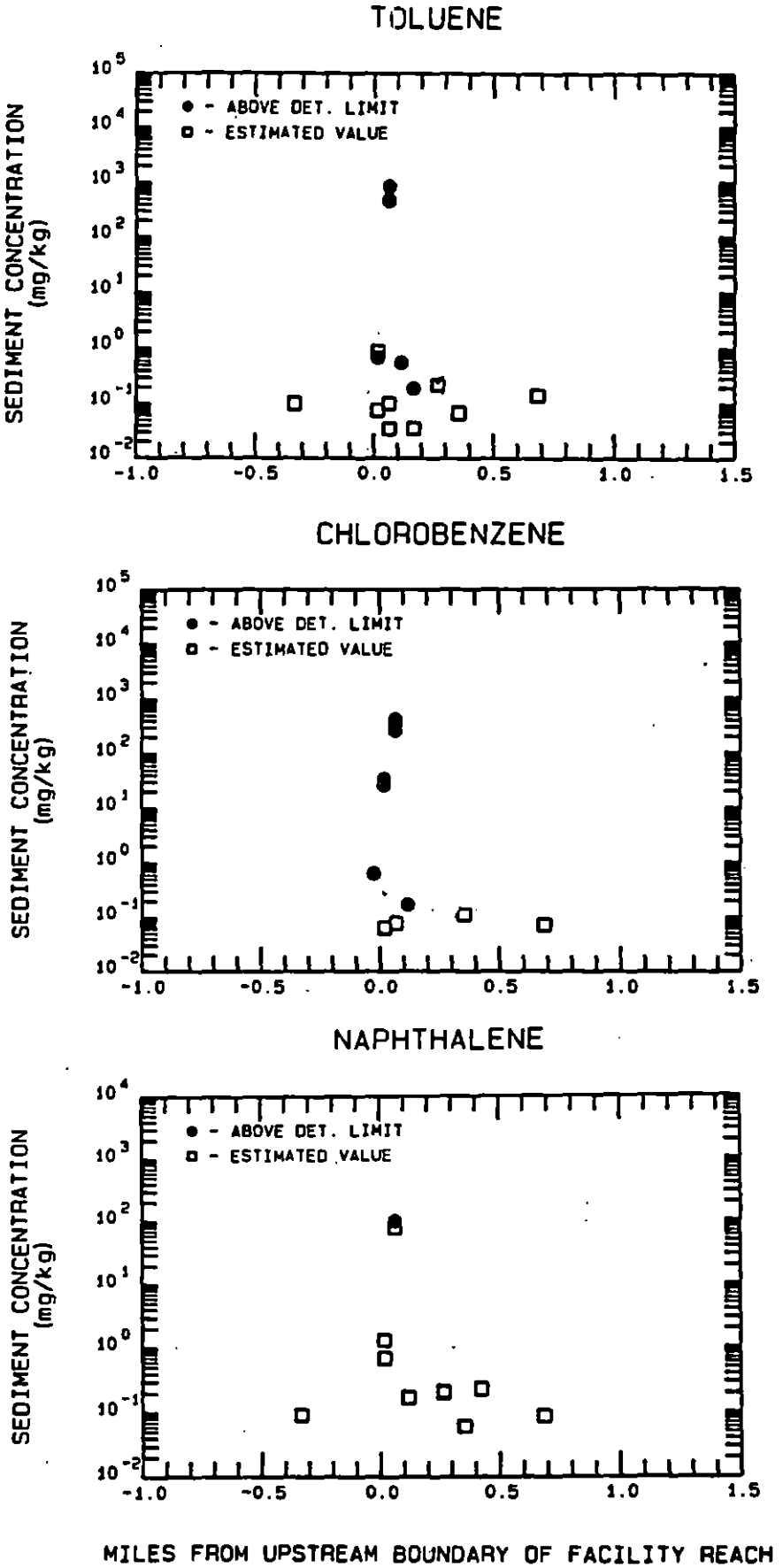


Figure E-2. PAWTUXET RIVER RCRA PHASE I SEDIMENT ORGANIC CHEMICALS DATA, 1990-1991

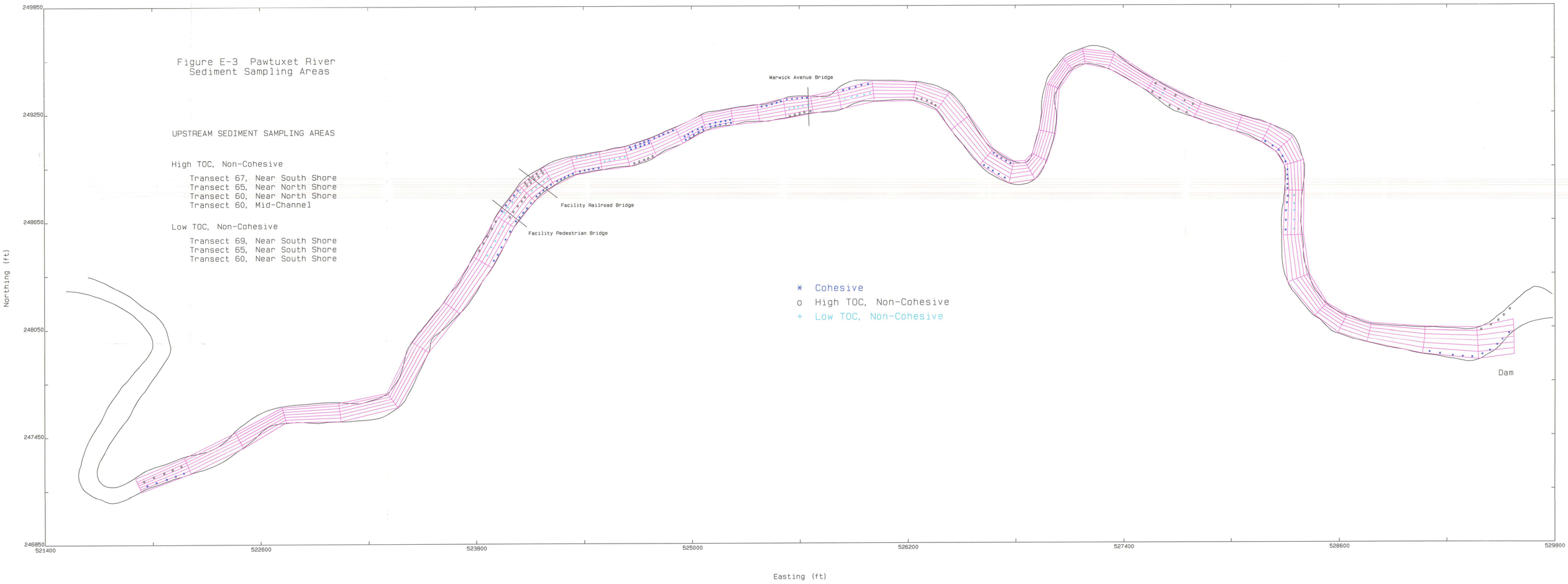
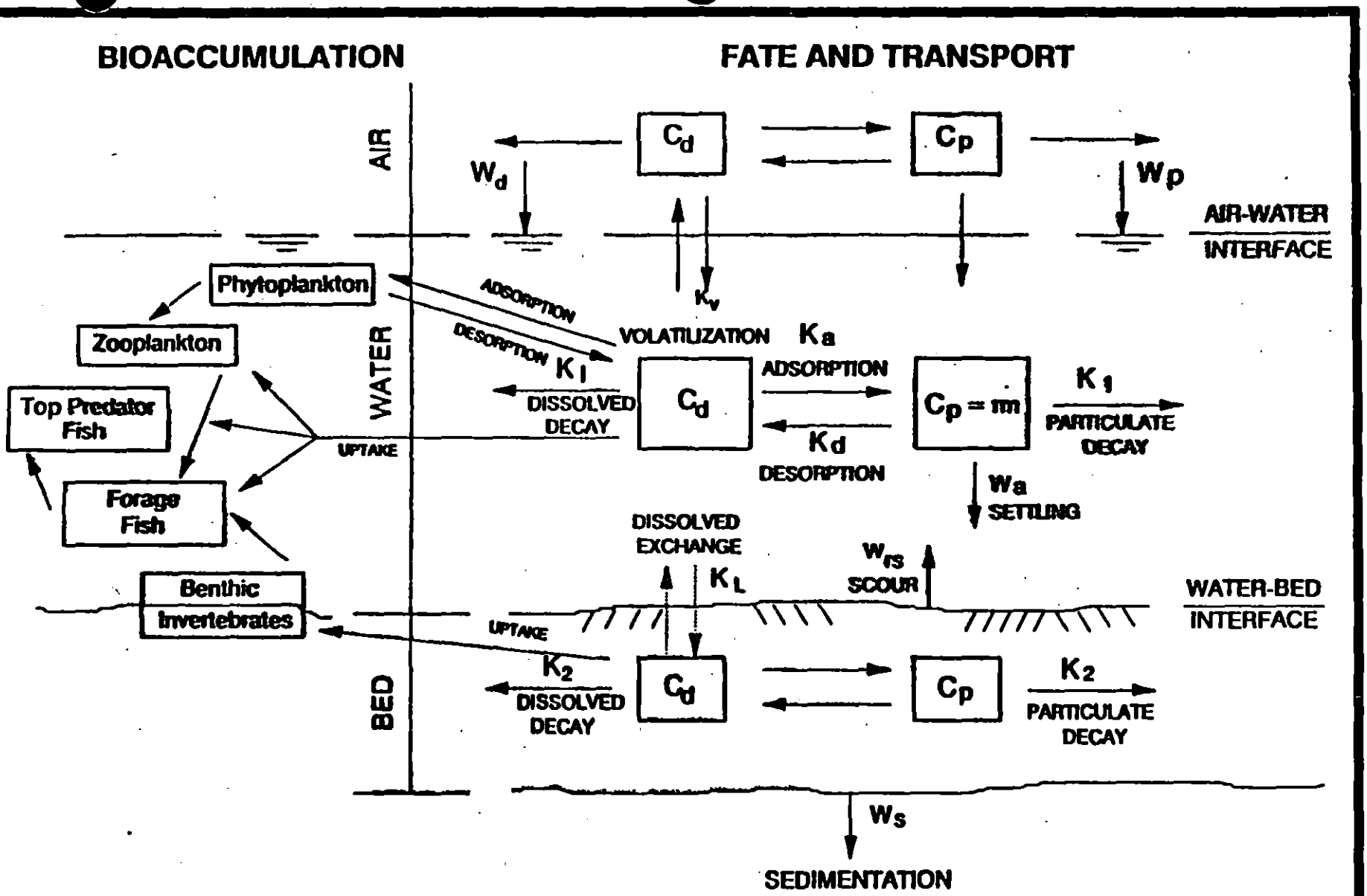


Figure E-3 Pawtuxet River Sediment Sampling Areas



A FLOW DIAGRAM OF WASTOX PROCESSES
HYDROQUAL, INC.

Figure E-4.

APPENDIX F
BASIS FOR PHASE II RELEASE CHARACTERIZATION SAMPLING PLAN FOR THE LOWER FACILITY REACH

The proposed sampling plan for the Phase II Release Characterization (Section 5.3.4) is comprised of two rounds. The plan states that in the lower facility reach Round 1 sediment samples will be collected to a depth of six inches (or to the penetration depth of the sampler). This data will be used to evaluate the horizontal extent of contamination. If contamination is detected in the lower facility reach from the Round 1 analytical results, the vertical extent of contamination in the lower facility reach will be evaluated in Round 2. If no contamination is detected in the lower facility reach in Round 1, evaluating the vertical extent of contamination in the lower facility reach will not be warranted. This section describes the basis for the proposal to evaluate the vertical extent of contamination in the Phase II Release Characterization sampling plan for the Lower Facility Reach. The following discussion addressed this issue through consideration of biological and contaminant transport issues.

Biological Considerations

The benthic community of the Pawtuxet River is dominated by tubificid worms and chironomid larvae. Also present are leeches, planeria, many families of insects, amphipods, isopods, decapods, snails and bivalves. The substrate of the Pawtuxet River is largely composed of sand or larger particles and has limited amounts of clay. The majority of the species identified are associated with surficial sediments through their ecology. Bivalves are filter feeders and depend on the stream current to provide a continuing source of food. Crustaceans rely on the course particulate organic matter of recent deposition for food. Oligochartis, which include the tubificid worms, however, feed through ingestion of sediment in the way that terrestrial earthworms do. Oligochartes are known to penetrate to depths greater than 10 cm in fine-particulate sediment such as mud and silt. The Pawtuxet River does not provide such a substrate, and benthic biota below the surficial sediments are not expected to be common near the site. The benthic community and nektonic species are expected to be associated with the surficial sediments and not the older, deeper sediments of the Pawtuxet River.

Contaminant Transport Considerations

The model that has been developed to simulate the suspended transport of fine-grained sediment, both cohesive and non-cohesive, in the Pawtuxet River utilizes the results of extensive laboratory and field studies to specify the parameters governing deposition and resuspension processes. The SEDZL modeling framework, which accurately and realistically simulates cohesive resuspension and deposition, including the effects of flocculation, has been modified to include the simulation of non-cohesive suspended transport. The need for including non-cohesive suspended load in these simulations is due to the presence of relatively high concentrations of total organic carbon (TOC), which adsorbs organic chemicals and heavy metals, in non-cohesive sediment bed deposits. Several field studies were conducted during the spring of 1992 to collect bathymetric, stage height, suspended solids and sediment bed data. The hydrodynamic and sediment transport models were calibrated and validated during a 33 day period, which included 2 high flow events, each of which approximately correspond to the annual flood. The successful calibration and validation exercise indicates that the model can be confidently used as a predictive tool.

Sediment transport in rivers is episodic by nature with a major fraction of the load transported during a few days of flooding each year. This characteristic of rivers makes it necessary to examine the effects of extreme events, i.e., rare floods, on the resuspension of sediments when considering the fate of contaminants residing in the sediment bed. Use of a calibrated and validated sediment transport model, that realistically simulates deposition and resuspension processes, makes it possible to quantitatively delineate the sources of suspended load in a riverine system. Spatial variations in sediment bed erosion can be predicted by the model for a particular flood. These predictions can then be coupled with measured sediment bed properties, e.g., grain size distribution and TOC concentration, to estimate the probabilities of contaminant resuspension.

A flood frequency analysis for the lower Pawtuxet River was carried out to estimate the magnitude of various extreme events. An analysis of 51 years of flow data collected at the USGS Cranston gauging station, from 1940 through 1990, was conducted using a standard USGS method for determining flood flow frequencies (USGS, 1981). This method utilizes a Log-Pearson Type III distribution to estimate flood flow frequencies. The results of this analysis indicated that flow rates of 3,500 and 5,200 cfs correspond to the 10-year and 100-year floods, respectively, downstream of the confluence of the Pocasset River. These high flow events can be contrasted to the mean flow rate of 410 cfs and the annual flood of 1,450 cfs.

The sediment transport model was used to examine the effects of the 10-year and 100-year floods on sediment bed erosion in the Pawtuxet River. Only resuspension was considered in these calculations, the upstream and tributary sediment loads were set to zero and assumed to have negligible effect on the total amount of bed erosion during the flood. The predicted erosional depths due to the 100-year flood in the vicinity of the facility are illustrated on Figure 1. Erosional depths are generally less than 0.2 cm in this reach, with a few small areas of erosion to depths greater than 1.0 cm (0.4 inch). This type of erosional pattern was predicted for the rest of the river; relatively shallow erosion in most of the river channel with small, localized pockets of deeper erosion. The results of these calculations indicate three small areas, defined by model segmentation, where significant erosion may occur during extreme flow events, see Figure 2. The depth of erosion in these segments ranges from 1.3 to 10.9 cm (0.5 to 4.3 inches) for the 10-year flood and from 3.5 to 15.9 cm (1.4 to 6.3 inches) for the 100-year flood. The areas, or segments, in which the highest erosion occurs are relatively small, with typical dimensions of 5 meters wide by 50 meters long. Outside of these segments, erosional depths typically range from 0.2 to 1.0 cm (less than 0.5 inch).

Results of the extreme event simulations indicate that sediment bed erosion to depths of 6 inches will only occur during rare floods, e.g., 100-year flood, and then only in very limited areas of the river. Thus, sediment bed contaminants available for resuspension in the Pawtuxet River can generally be regarded as limited to the top six inches of the bed. Contaminant concentrations obtained from a surficial sediment bed sample, i.e., collected from the top six inches of the bed, can confidently be assumed to represent all of the potential erodible mass of contaminants at the sample location, except possibly at the three locations indicated on Figure 2. Locations that yield surficial samples with non-detectable contaminant concentrations do not require retrieval of deeper cores and subsequent contaminant analysis at depths greater than six inches. Obtaining that data would not produce useful information for the contaminant fate and transport modeling effort.

Even though 3 small areas of potentially high resuspension have been identified through model simulations, with only 2 of the locations approaching six inches of erosion as a result of a 100-year flood, sampling deeper in the bed may not be automatically warranted in those areas. Those segments experience very high bottom shear stresses during floods, which causes the high

erosion. The bathymetry and geometry of the Pawtuxet River create those areas of relatively high bottom shear stress, not only during flood conditions but also during normal flow conditions. This relatively high shear stress environment will tend to inhibit deposition in those locations; areas of high erosion during floods will typically have low deposition rates during low to moderate flow rates. Deep burial of contaminated sediments in areas of high erosion is thus unlikely. Therefore, if non-detectable contaminant concentrations are found in surficial samples obtained in the three areas of potentially high erosion, then deeper sampling is not warranted.

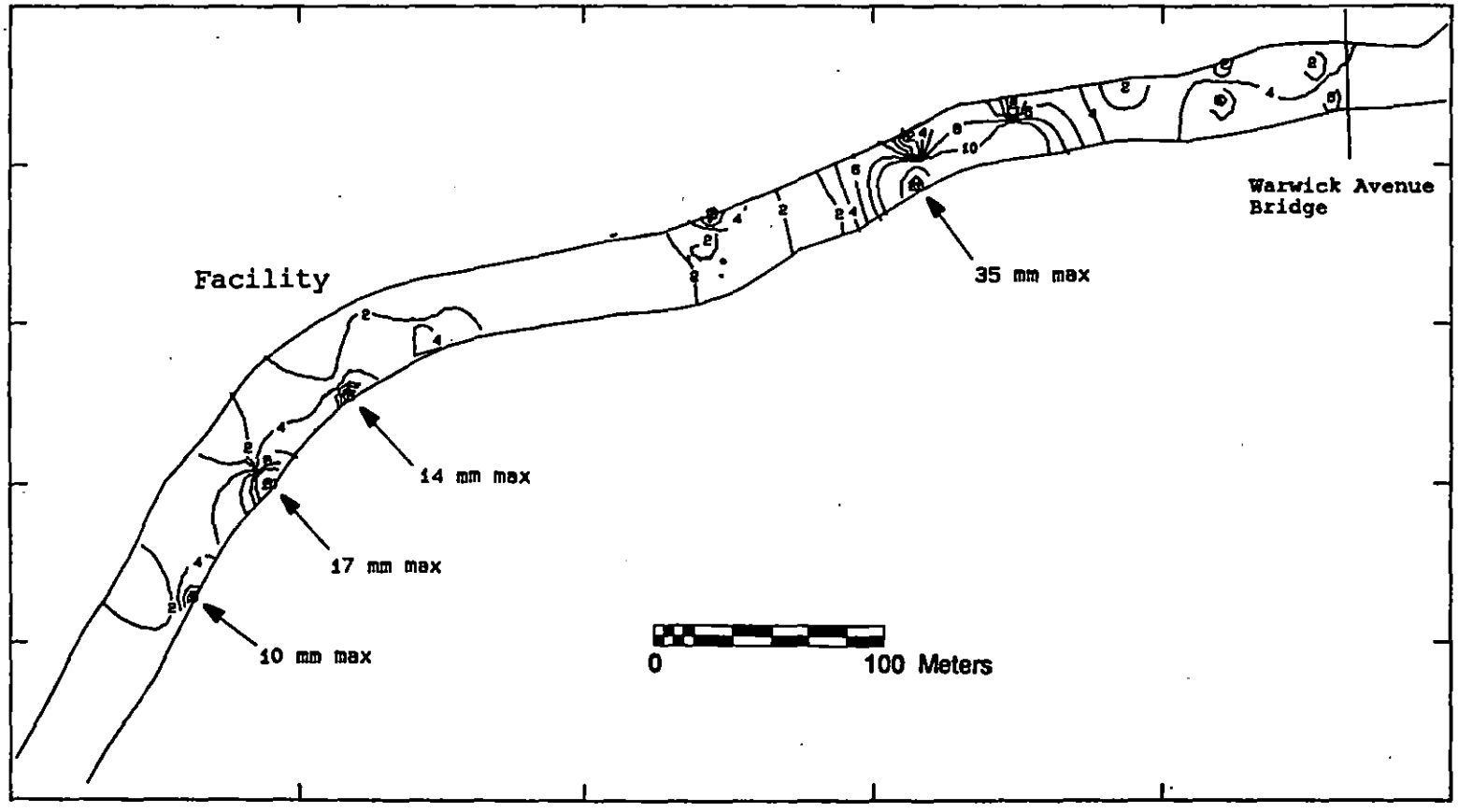


Figure F-1 Predicted Erosional Depths Resulting From 100-year Flood (5200 cfs)

Flood (yrs)	Q (cfs)	Maximum Erosion (cm) ①	②	③
10	3500	3.6	10.9	1.3
100	5200	14.7	15.9	3.5

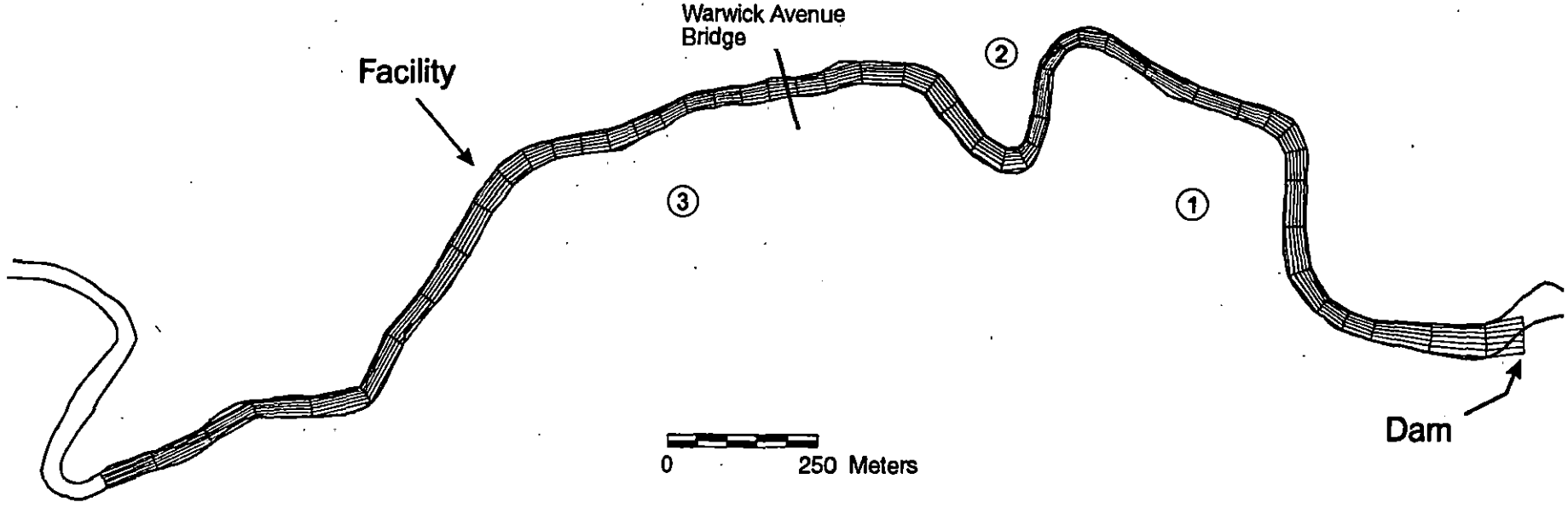


Figure F-2 Locations of Predicted Maximum Erosion During Extreme Flow Events